Canada – Newfoundland
Flood
Damage
Reduction
Program

June, 1986

Study of Possible Remedial Measures for the Steady Brook Area

Steady
Brook

CUMMING-COCKBURN & ASSOCIATES LIMITED

Consulting Engineers

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7137
June 10, 1986

Canada-Newfoundland Flood Damage
  Reduction Program
c/o Government of Newfoundland and Labrador
Department of the Environment
Water Resources Division
P.O. Box 4750
St. John's, Newfoundland
A1C 5T7

Attention: Dr. Wasi Ullah, P. Eng.

Dear Sir:

Re: Remedial Measures Study of the
    Steady Brook Area

We take pleasure in submitting our final report on the above mentioned study.

The methodology and main findings of our investigations are discussed herein along with our recommendations on potential remedial measures.

We appreciate the opportunity to have been of assistance to you on this most interesting project.

Yours very truly

CUMMING-COCKBURN & ASSOCIATES LIMITED

H S Belore

H. S. Belore, P. Eng.
Manager, Water Resources Division

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STUDY OF POSSIBLE REMEDIAL MEASURES
FOR THE
STEADY BROOK AREA

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The information and conclusions presented in this report were derived with assistance from several individuals and organizations.

The following members of the Flood Damage Reduction Technical Committee provided significant input and direction throughout the study.

- Dr. W. Ullah	Government of Newfoundland and Labrador Department of Environment
- Ms. E. Langley	Inland Waters Directorate Environment Canada
- Mr. R. Picco	Project Engineer - Canada-Newfoundland Flood Damage Reduction Program

Background information collected by the Water Resources Division of the Newfoundland Department of Environment proved most useful during these investigations. Essential data was also provided by the staff of Thorne Real Estate Ltd. in Corner Brook.

The key members of the study team were drawn from the combined staff of Nolan, Davis & Associates Limited and Cumming-Cockburn & Associates Limited. The responsibilities of these members with respect to the various components of these investigations are noted as follows:

Mr. B. Davis, P. Eng.	- Project Director - Field Work/Interviews
Mr. H. S. Belore, P. Eng.	- Technical Director
Mr. B. R. Plazek, P. Eng.	- Assessment of Remedial Measures
Mr. J. F. Juffs, P. Eng.	- Remedial Measures
Mr. C. K. Jarratt, P. Eng.	- Hydrologic Analyses
Mr. S. J. Smith, C.E.T.	- Hydraulic Analyses - Economic Analyses - Report Graphics
Mr. W. Pye	- Physical Surveys and Interviews
Mr. D. C. Kerr, B.Sc.	- Environmental Analyses
Ms. P. J. Thompson	- Report Graphics

The study team wishes to acknowledge their appreciation for the invaluable comments provided by the residents of the Community of Steady Brook with respect to local flooding conditions, historical damages and other demographic information utilized in this study.

We would also like to express our appreciation for the time and effort of all others who contributed to this project by way of information, discussions and otherwise.

1.0 INTRODUCTION

1.1 General

Historically, the development of urban centres in many areas of Canada including Newfoundland, has taken place on flood prone lands. An increasing trend towards urban developments in Canada has resulted in an increased potential for higher flood losses. A nation-wide survey of potential flood hazards (1) has indicated that more than 200 communities in Canada have some developments located in flood hazard areas. In particular, a number of recent reports have well documented the serious consequences of flooding in Newfoundland, and more specifically in the Steady Brook area (2,3,7,8,9,11,21,22).

There is continuing pressure to develop additional lands in the Steady Brook floodplain areas. This is evidenced by recent attempts to provide some form of flood and erosion control along parts of the Humber River and Steady Brook. The development pressures have led to an increased potential for future flood losses in the Steady Brook and Humber River floodplain.

On May 22, 1981, the Province of Newfoundland and the Government of Canada entered into a General Agreement Respecting Flood Damage Reduction. The main objective of this Agreement is to reduce the potential for flood damages in floodplains and along the shores of lakes, rivers and the sea. This Agreement also recognizes that the potential for future flood damages can be reduced by controlling the development in the areas prone to flooding.

As part of the General Agreement Respecting Flood Damage Reduction, the two levels of government are allowed to enter into a number of other agreements on specific aspects of flood damage reduction, including but not limited to;

NOTE: (1) Number(s) in brackets denote sources given in the list of references which comprises Section 9.0 of this report.

land use planning, flood proofing, flood risk mapping, flood forecasting, flood control works and flood studies. To provide for the identification and delineation of flood prone areas in Newfoundland, the "Agreement Respecting Flood Risk Mapping" was also signed on May 22, 1981. These agreements were amended in May, 1983 and a related "Studies Agreement" was signed in June, 1983. In this report, projects completed under these agreements are referred to as work done under the Canada-Newfoundland Flood Damage Reduction Program (abbreviated to CNFDRP).

The reach of the Humber River from the outlet of Deer Lake to 0.5 km downstream of its confluence with Steady Brook and the portion of Steady Brook downstream of the falls was considered to be of high priority in regard to the potential for reducing future flood losses and was one of the first areas in the Province to be studied in detail under this program. As such, a recent investigation by Cumming-Cockburn & Associates and Nolan Davis & Associates Limited (8) was undertaken to determine flood discharge and water levels and to identify flood prone areas and possible remedial measures along the Humber River and Steady Brook.

The primary purpose of the present study is to assess structural or non-structural measures for flood damage reduction and/or to assess regulations for preventing future development in the flood prone areas identified as a result of previous investigations.

1.2 Authorization and Scope of Study

The agreements previously mentioned provide for the establishment of two committees; the Steering Committee which is responsible for general administration of the agreements and the Technical Committee which provides technical support to the Steering Committee. Nolan Davis & Associates Limited, in association with Cumming-Cockburn & Associates Limited were commissioned by the Newfoundland Department of Environment on behalf of the Steering Committee to undertake a "Study of Possible Remedial Measures for the Steady Brook Area". As described in the Terms of Reference (2), the main objective of this investigation was to provide recommendations on the feasibility of implementing measures to reduce flood damages in the Steady Brook area floodplain affected by both the Humber River and Steady Brook.

The following points summarize the overall scope of the investigations:

1. Examine background information and interview residents to document the severity of the flooding problems and causative factors.
2. Review natural and man-made changes in the stream channel and watershed area affecting flooding.
3. Examine town planning and subdivision regulations as they affect the flood damage potential.
4. Develop stage-damage relationships applicable for the study area.
5. Identify relevant structural and non-structural flood management alternatives.
6. Evaluate the effectiveness of the identified flood management schemes utilitizing the modelling work undertaken for the Steady Brook area Hydrotechnical Study.
7. Estimate capital and operating costs of flood management alternatives.
8. Estimate environmental and social impact of flood management alternatives.
9. Determine benefit-cost ratios of the most promising flood management alternatives.

1.3 Study Area Description

The general location of the study area is depicted on Figure 1.1. Within this area the Community of Steady Brook is located on the south bank of the Humber River between Corner Brook and Deer Lake.

The upstream drainage area is comprised of the Humber River system which has a drainage area of over 7800 km^2 to Steady Brook. The Humber River watershed is drained primarily by two main branches; the Upper Humber River and Grand Lake. The Upper Humber River drains a watershed area of over 2100 km^2 to its outlet at Deer Lake and remains in a relatively natural state (with respect to both land use and streamflow regulation). The watercourse originates in the north in Gros Morne National Park and flows in a southerly direction, eventually outletting into Deer Lake. The subwatershed representing the discharge from Grand Lake can be characterized as being relatively large (over 5000 km^2). A significant portion of this subwatershed consists of Grand Lake itself, which is used to produce hydroelectric power. The outflow from Grand Lake discharges to Deer Lake which is an unregulated natural reservoir. Downstream from Deer Lake, the watercourse flows in a southwesterly direction to the Gulf of St. Lawrence.

As previously discussed, a portion of the study area consists of floodplain lands adjacent to Steady Brook. This is a relatively small watercourse which drains an area of 81.4 km^2, and outlets into the Humber River at the Community of Steady Brook.

A large portion of the historical flood damages along the Humber River have occurred in the low-lying portions of the Community of Steady Brook. This is primarily due to flood conditions on both the Humber River (which can occur at any time of the year) and Steady Brook (which occurs primarily during spring runoff).

Recent studies, in particular the "Hydrotechnical Study of the Steady Brook Area" have identified and assessed the factors affecting flooding and have identified flood risk areas (8). The areas subject to a flood hazard include:

1. The Community of Steady Brook
2. A small area of development in the vicinity of Russell
3. A small area of development in the vicinity of Harrison
4. The area of Governors Point at the outlet of Deer Lake.

These areas are identified on Figure 1.2. On the basis of the results of previous investigations, the flooding problems experienced at the flood hazard locations appear to be a result of:

- The discharge capacity of the main channel in comparison to the magnitude of the discharge from the Humber River and Steady Brook for specific rainfall/snowmelt events.
- Ice jam occurrences (restricted to lower reaches of Steady Brook).
- Development occurring with the natural floodplain of the river valley.
- Operation of Grand Lake.

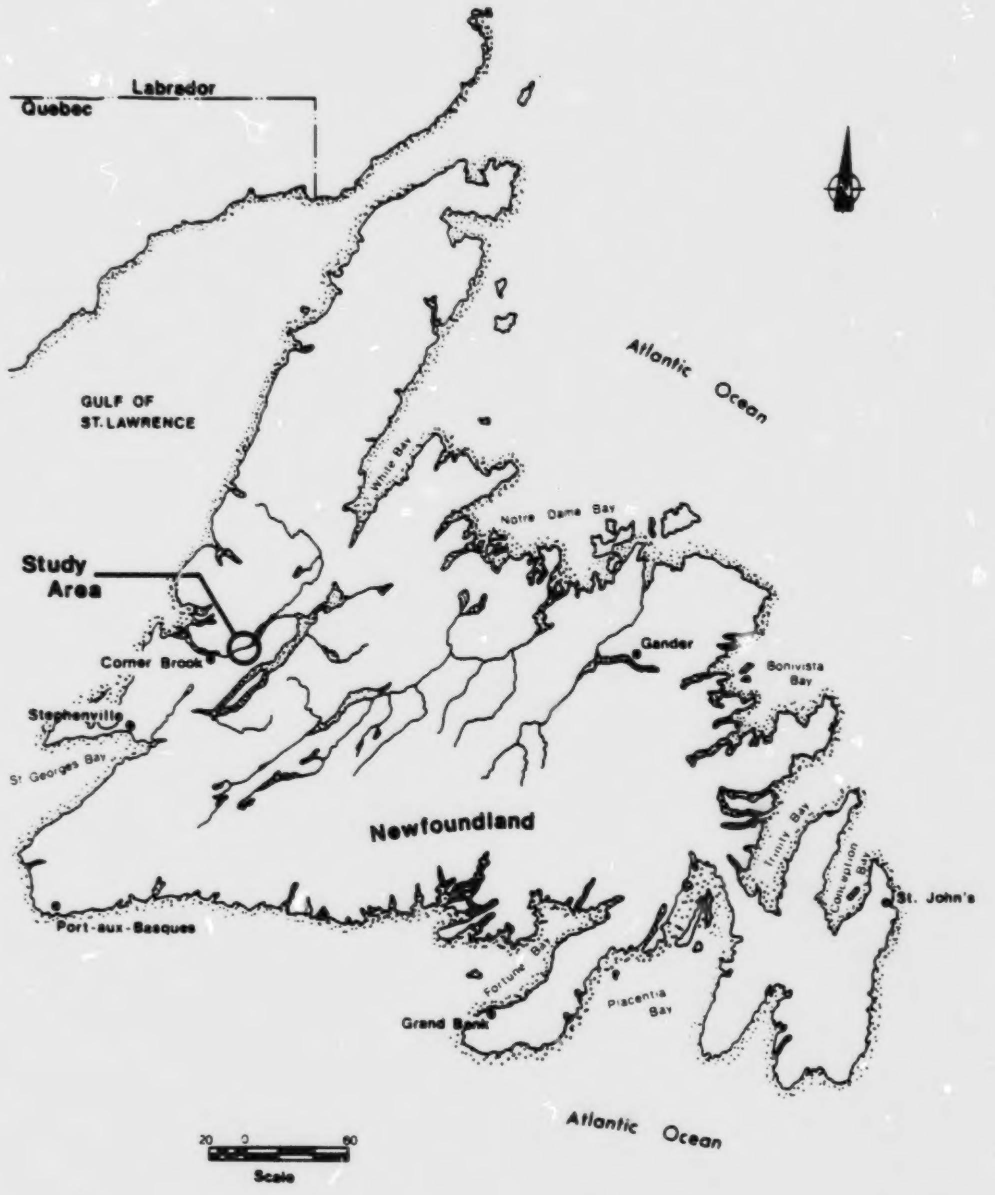
1.4 General Overview of Study Methodology

The investigations were undertaken systematically using a two-phased approach. Phase I involves the preliminary investigation of alternative flood mitigative schemes. This is followed by Phase II which is a more detailed evaluation of the selected schemes.

Initially an investigation of the severity of the flood hazard condition was undertaken. This included review of existing information, field topographic and reconnaissance surveys (including interviews with local land owners) and an assessment of the potential flood damage. The results of this analysis are summarized in Section 2.0.

After identifying the present flood damage characteristics of the study area, alternative options for flood control were evaluated. The alternatives considered included "Do Nothing", "Non-structural" and "Structural" approaches. The identification, evaluation (e.g. engineering, economic and environmental) and comparison of alternative flood mitigative measures are described in Sections 3.0 and 4.0.

The preferred solutions for minimizing the flooding potential which exists within the four identified flood hazard areas are described in Sections 5.0 to 8.0, which comprise Phase II of the investigations.


Labrador
Quebec
GULF OF
ST. LAWRENCE
Atlantic Ocean
White Bay
Notre Dame Bay
Study
Area
Corner Brook
Stephenville
St Georges Bay
Gander
Bonivista
Bay
Trinity Bay
Conception Bay
St. John's
Newfoundland
Port-aux-Basques
Fortune Bay
Grand Bank
Placentia
Bay
Atlantic Ocean
20 0 60
Scale

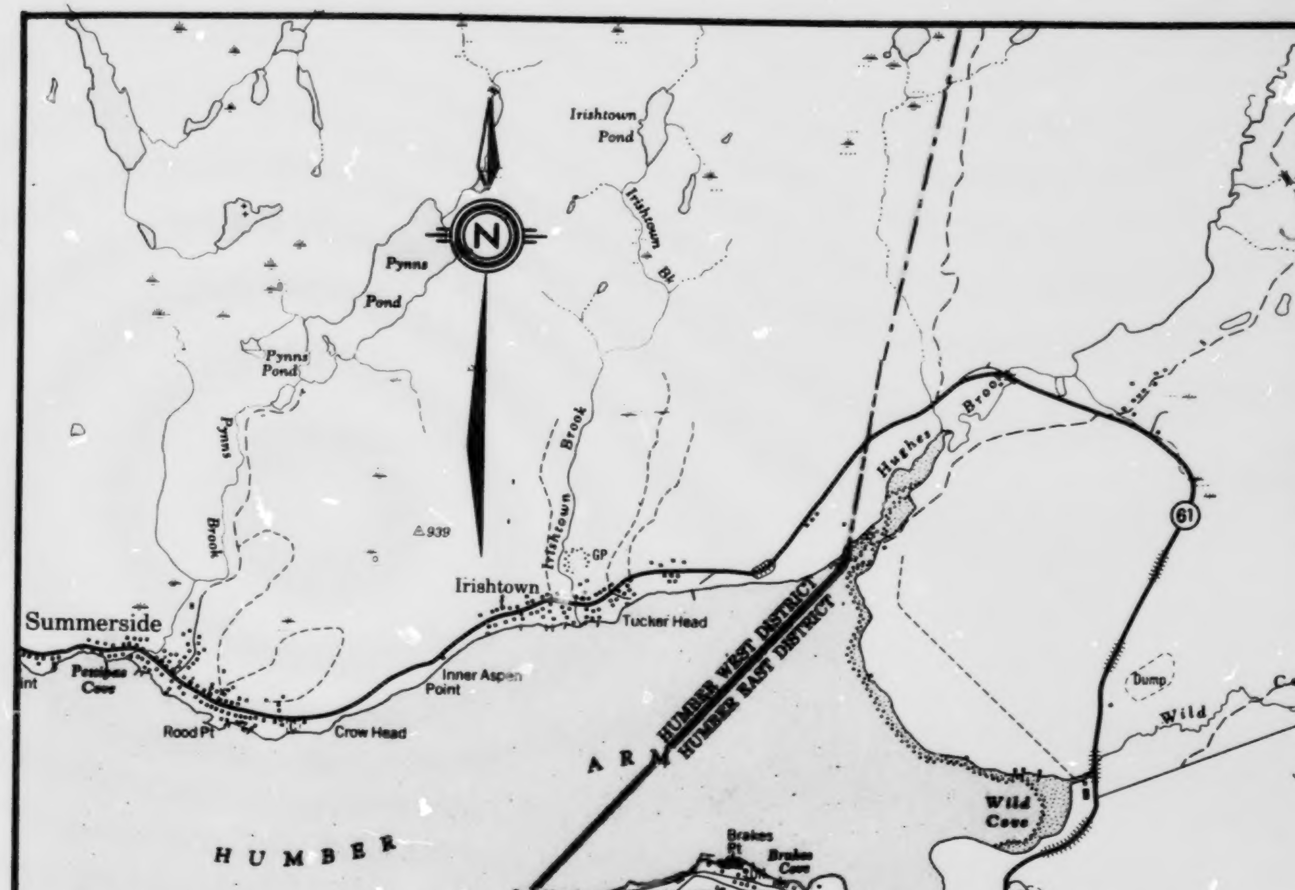
Canada - Newfoundland
Flood Damage Reduction Program

General Location of
Study Area

NOLAN DAVIS & ASSOCIATES

CUMMING COCKBURN

Figure 1.1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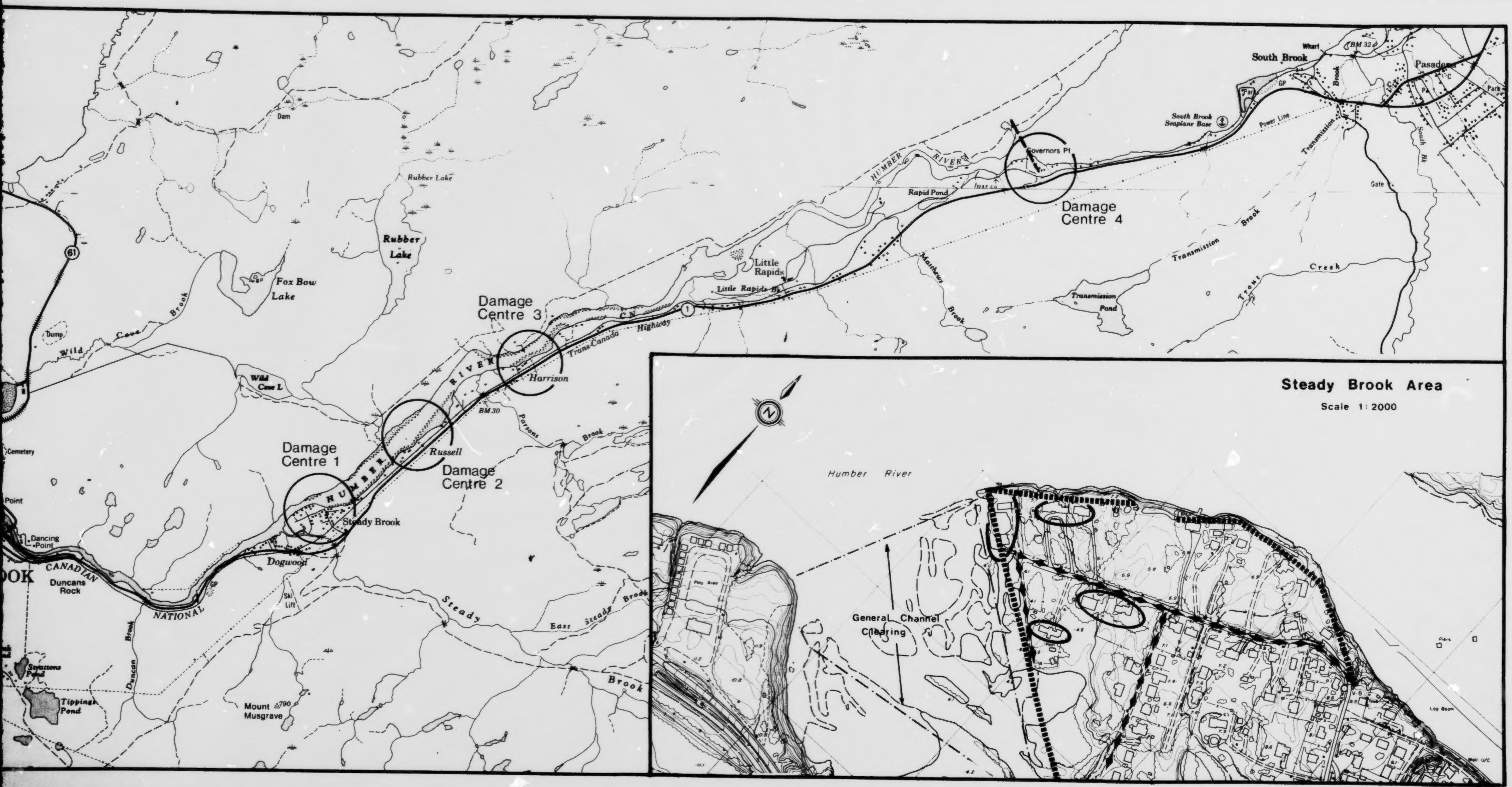
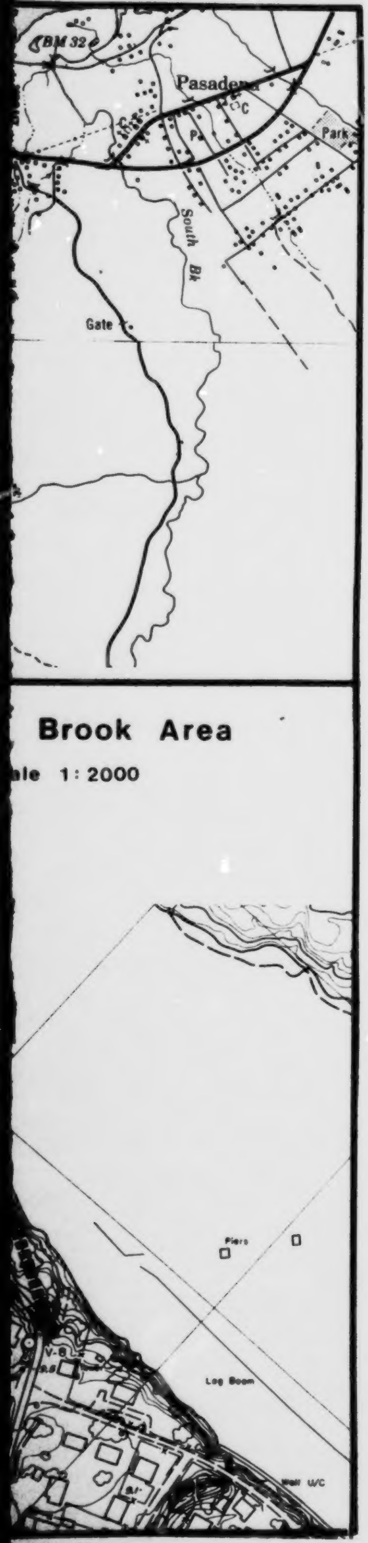
Irishtown Bk
Pynns Pond
Pynns Pond
Pynns Brook
Irishtown Brook
939
GP
Irishtown
Summerside
Tucker Head
Hughes Brook
61
Inner Aspen Point
Penguin Cove
Rood Pt
Crow Head
HUMBER WEST DISTRICT
HUMBER EAST DISTRICT
HUMBER ARM
Dump
Wild
Wild Cove
Brakes Pt
Brakes Cove
Seal Head
Cemetery
Church Cove
DeGrouchy Pt
Mill
Quarry
Gravel Pits
Factory
Oil
46
Crow Hill
Radio 105'
Television
Hosp
Johns Point
BM 30
Radio
Television 120'
Quarries
Dancing Point
Pk
Oil
Hosp
Armoury
CORNER BROOK
CANADIAN
Duncans Rock
46A
Auto Wrecker
Golf Course
Quarry
Massey Drive
Link Pond
GP
Bells
Radio 225'
South Bells Bk
Gulch Bk
City Limits
Radio 230'
Transformer Station
Struttons Pond
Tippings Pond
Corner
Water Pipeline
Watsons
Trout Pond


South Brook
Wharf
BM 32
Pasadena
Brook
Park
South Brook Seaplane Base
Power Line
Transmission
South Bk
Gate
Governors Pt
HUMBER RIVER
Rapid Pond
BM 29
Damage Centre 4
Matthews Brook
Transmission Brook
Trout Creek
Transmission Pond
Little Rapids
Little Rapids Bk
CN
Trans-Canada Highway
1
Damage Centre 3
Harrison
RIVER
BM 30
Parsons Brook
Russell
Damage Centre 2
Damage Centre 1
HUMBER
Steady Brook
Dogwood
Rubber Lake
Dam
Fox Bow Lake
Cove Brook
Wild
Dump
61
Wild Cove L
Cemetery
Point
Dancing Point
CANADIAN NATIONAL
Duncans Rock
GP
Ski Lift
Steady Brook
East Steady Brook
Duncan Brook
Simmons Pond
Tippings Pond
Mount Musgrave
790
Steady Brook Area
Scale 1: 2000
N
Humber River
General Channel Clearing
Play Area
Piers
Log Boom



Brook Area

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Index to Potential Remedial Work Schemes

▪▪▪▪▪▪▪▪▪▪▪▪▪▪	Earth Berm
◆◆◆◆	Raise Roadway
— — — —	Discharge Control Structure
○	Local Floodproofing

SOURCE: NOLAN, DAVIS & ASSOC. LTD.; CUMMING-COCKBURN & ASSOC. LTD.
"HYDROTECHNICAL STUDY OF THE STEADY BROOK AREA"
CANADA-NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM,
OCTOBER, 1984

Scale 1:500,000

Canada - Newfoundland
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Location of Flood Hazard Areas

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Figure 1.2

Phase I:

Preliminary Investigations

2.0 PRELIMINARY EVALUATION OF FLOOD CONDITIONS

2.1 General

The purpose of the Phase I investigations was to identify and screen all relevant potential flood mitigative measures which might be adopted for the purpose of reducing flood damages in the study area.

The primary objectives of the Phase I investigations are summarized below and expanded upon in the following sections.

1. Review and examine the existing flood characteristics in the study area including all previous background information and flood documentation in the area.

2. Conduct interviews with local residents within the flood risk area and Town officials to determine their perspective on the flood situation. This includes inquiries in regard to severity, frequency, hazardous conditions and cases of specific incidents; also any recommendations on suggested solutions were solicited.

3. Examine geomorphological processes and determine if they have a significant role in finding a solution to the flood damage problem.

4. Examine planning policy, subdivision and development regulations to determine if these have had any effect on the flood damage either directly or indirectly.

5. Develop stage-damage relationships in order to evaluate various methods of protection in relation to various design water levels.

6. Identify potential structural and non-structural alternatives including, but not limited to, dykes, dams, channel improvements (including existing in-channel hydraulic structures), diversion channels, early flood warning mechanisms, contingency planning, floodproofing, ice management and retention techniques (including

dams, weirs, blasting, dusting and ice removal), property acquisition and zoning, that may offer relief from flood damage in the future.

7. Make rough, order-of-magnitude estimates of capital and operating costs of any promising works compared to potential benefits to the public and private property owners.

8. Review the environmental impact of the various measures, assessing any potentially beneficial or detrimental effects, such that they may be incorporated into a comparison of alternative measures.

9. Make estimates of the social impact of the various measures considered for comparison to any alternate measures which warrant consideration.

10. Submit an interim report to the Technical Committee comparing the various measures and priorizing these on the basis of benefit/cost ratios, environmental impact and social acceptability.

The following sections describe the investigations undertaken during Phase I:

2.2 Background Information

Documentation on historical flooding along the Humber River covers the period 1944 to present (11, 8). Investigations documenting flood conditions in the Humber River watershed in recent years have found that the predominant cause of flooding at various locations has been excessive rainfall during the spring months which leads to rapid snowmelt and peak flows, although flooding can occur at any time of the year. Further, it is also noted that the effect of ice and debris jamming along Steady Brook can increase the flood risk to these areas (8).

However, the increased frequency of damage reports in recent years (post-1974) may be indicative of additional development of floodplain lands.

Existing regional flood frequency studies on peak flows for the island portion of the Province were useful in providing an overall assessment of flood characteristics in the area (3, 25). This information indicates that peak flows along the Humber River frequently (approximately every 1:5 years) exceed the channel capacity, requiring use of additional conveyance capacity in natural floodplain areas.

A report pertaining to the high flows in the Humber River system during May 1969 was undertaken by Shawmont Newfoundland Ltd. (29). This report discusses the causes and effects of the high levels and flows on the Humber River system during that time period. In addition, the impacts and effects of the Bowater Power Company hydroelectric development on Grand Lake were also analysed with respect to the May 1969 flooding. The report concludes that if the hydroelectric plant had not been built, then the flooding, past and future, would be at least as severe and probably more severe than with the development of the storage system. These statements apply equally to Deer Lake and the reach of the Humber River between Deer Lake and Steady Brook. With respect to the period of high flows which occurred in May 1969, it was concluded that the hydro development had a beneficial effect on the water levels and flows downstream from Deer Lake. It was also concluded that the addition of the Indian Brook Diversion had a negligible influence on flooding at downstream locations.

Subsequent to high flows in the Grand Lake system during May 1981, the Department of Environment undertook an investigation on the flooding of the area (9). This preliminary report briefly reviews the recurring flooding problem experienced by the residents of the Humber Valley and the reservoir operational requirements of the Bowater Power Company. The investigation concludes that the Steady Brook area is prone to flooding even without any contribution from the Main Dam spillway as the Humber River channel capacity is only about 25,000 cfs (708 m^3/s). Other findings were that the regulatory effects of the reservoir may be significant for small floods. However, for the relatively large floods the effects were insignificant. It was also pointed out that in certain hydrologic situations and operational schemes, the Grand Lake reservoir may have adverse downstream effects. Recommendations included the completion of flood risk maps for the area and the implementation of a flood warning system. It was also recommended that upgrading be undertaken on existing hydrometric stations and the snow survey program.

Some flooding at the Community of Steady Brook has been attributed to the construction of the Trans Canada Highway on the southern shore of the Humber River. Two reports entitled, "Humber River Flooding at Steady Brook" were completed for the Newfoundland Clean Air, Water and Soil Authority in 1972 (21, 22). The first investigation consisted of a review of the report by Shawmont Newfoundland Ltd. undertaken for the Bowater Power Company Ltd. subsequent to the 1969 flooding at Steady Brook (29). This review confirmed several of the findings previously stated in the Shawmont study, and recommended an additional study to determine the factors contributing to periodic flooding of the Steady Brook area and to investigate the feasibility of remedial works which would alleviate undesirable conditions. The effect of infilling a small part of the Humber valley section during construction of the Trans Canada Highway on flood levels along the Humber River was also assessed, and was reported to be relatively insignificant.

Various structural alternatives were discussed for reducing flood damages. These alternatives ranged from major schemes such as upstream storage, and widening of the channel, to more localized alternatives such as dykes and floodproofing. An analysis of the cost of these measures and their potential to reduce the physical extent of the hazard was also addressed. Non-structural measures (such as development of an early flood warning system) were assessed. However, this discussion was substantially more qualitative in nature compared to the assessment of possible structural modifications. It was generally concluded that the most cost effective means of reducing the flood potential along the Humber River would be floodproofing or relocation of highly flood susceptible structures, or the refinement of operating policies at the Grand Lake control structure to restrict outflows to the downstream reaches.

Most recently, a "Hydrotechnical Study of the Steady Brook Area" was undertaken by Nolan Davis & Associates Limited in conjunction with Cumming-Cockburn & Associates Limited under the Canada-Newfoundland Flood Damage Reduction Program (8).

The primary purpose of the study was to determine flood discharge and associated water levels, and flood prone areas, for the 1:20 and 1:100 year recurrence interval flood events. A secondary objective was to identify possible flood remedial measures for future investigation. The study area for the hydraulic and floodplain mapping investigations extended from the outlet of Deer Lake to just downstream of the confluence of Steady Brook with the Humber River.

Computer simulation techniques, which considered hydrologic conditions at upstream locations (e.g. snowmelt), and the effects of lake, reservoir and channel routing, were utilized in order to estimate the peak flow rates and associated flood levels in the study area.

The investigations led to the identification of the main flood hazard area as being the Community of Steady Brook from the Humber River to the C.N.R. trestle. Small areas of development in the vicinity of Humber Village, Russell, Harrison and Governors Point (at the outlet of Deer Lake) were also found to be subject to some flood risk.

The study identified the most attractive structural alternatives as (see also Figure 1.2):

1. A combination of raising the roads and berming or dyking at several locations within the Community of Steady Brook.
2. Individual flood proofing of structures located in flood fringe areas currently susceptible to potential flood damages.

The most attractive non-structural measures for reducing flood losses were noted as being:

1. Implementation of floodplain regulations to prevent development in flood susceptible areas
2. Review and improve the operational policies of the Grand Lake Dam such that the usefulness of this structure in reducing downstream flood peaks is improved
3. Implementation of a flood warning system to be used in conjunction with modified operation of Grand Lake.

The report concluded that the 1:20 and 1:100 year flood profiles and associated floodplains should be adopted and utilized for future regulation of development along the Humber River and Steady Brook and that additional feasibility investigations should be undertaken to analyse suggested remedial measures.

A subsequent report investigated the potential for using the SSARR Model as a component of the flood forecasting system (7). The report concluded that this technique would prove useful for flood forecasting on the Humber River.

The existing studies on the hydrologic, hydraulic and climatic characteristics of the Humber River and Steady Brook have confirmed that a high potential exists for future flood losses in the study area, particularly within the area of the Community of Steady Brook itself.

2.3 Review of Existing Condition

2.3.1 Flood Hazard Areas

The previous hydrotechnical study (8) identified four areas where a significant flood hazard exists (see Figure 1.2). They are:

- Damage Centre No. 1 - Community of Steady Brook
- Damage Centre No. 2 - Russell

- Damage Centre No. 3 - Harrison
- Damage Centre No. 4 - Governors Point.

Two conditions were considered for each of the design flood events; the expected mean discharge and the conditions associated with the upper 95% confidence level. Since ice jams may result in higher flood levels, it was decided to use the upper 95% confidence limit flows for the purpose of sensitivity analyses in evaluating remedial measures with higher flood levels.

The following is a brief discussion on the flood hazards associated with each site, the severity of the flooding condition and the causative factors.

i) Damage Centre No. 1 - Community of Steady Brook

This area is shown on Figure 2.1 and is relatively more urbanized compared to the other three damage centres identified. Under the 1:100 year mean flood level condition almost the entire area west of Falls Avenue would be inundated. This area includes about 15 residential structures and numerous ancillary structures. Five residential dwellings along the south bank of the Humber River would also be affected. In addition to residential structures, the following transportation routes would be affected under both frequent (i.e. 1:20 year event) and infrequent events (i.e. 1:100 year); Brook Road, Forest Drive, Falls Avenue and Woodland Place. Although the 1:20 year flood level drops approximately 0.8 m from that of the 1:100 year mean level, the same number of structures would be affected. The damage potential, however, is somewhat less severe as a result of the reduced flood level.

When considering the 1:100 year upper 95% Confidence Limit Floodline, the number of residential structures being affected increases appreciably to about 26.

The flood depths within the developed area of this damage centre ranged from a maximum of 2.9 m under the 1:100 year upper 95% confidence level to 1.2 m under the 1:20 year event. The width of the 1:100 year floodplain within the Community of Steady Brook was approximately 50 m wider than that of the 1:20 year event. Under the 1:100 year upper 95% confidence level, this width increased to in excess of 220 m. The limits of the flooding associated with the 1:20, 1:100 and 1:100 year 95% upper confidence level are delineated on Figure 2.1.

With regard to the potential for erosion it was found that the channel velocities at the outlet of Steady Brook were relatively low (less than 0.3 m/sec) during both frequent and infrequent events. The potential for erosion at the outlet would, therefore, be considered as being low. Along the Humber River the flow velocities were found to be higher, in the order of 1.3 m/sec, therefore representing a higher potential for erosion, although not considered to be severe compared to other areas.

ii) Damage Centre No. 2 : Russell

This reach of the Humber River is shown on Figures 2.2 and 2.3. A significant hazard was found to exist only under peak flow conditions associated with the 1:100 year upper 95% confidence limit. For this design flow condition, approximately five residential dwellings and numerous ancillary structures would be affected. The number of affected residential dwellings is reduced to one under the 1:100 year mean flood level. Under the 1:20 year event, only ancillary structures were found to be flood susceptible. No transportation routes (neglecting private drives) were found to be flood susceptible. The maximum depth of flooding within this damage centre varied from 2.6 m under the 1:100 year upper 95% confidence level to 0.9 m for the 1:20 year event. The maximum channel flow velocity was 0.6 m/sec.

The limits of flooding within this Damage Centre as shown on Figures 2.2 and 2.3 is attributed to the inadequate conveyance capacity of the Humber River. Based on discussions with the local residents, it was concluded that ice jam occurrences were not a problem.

iii) Damage Centre No. 3 : Harrison

Along this reach of the Humber River, as shown on Figure 2.4, seven residential structures were found to be flood susceptible under the 1:100 year mean level condition. This increased to eight when considering the upper 95% confidence limit. Under the 1:20 year event, the flood hazard dropped to two permanent structures. No transportation routes were found to be flood susceptible.

For the most part, the area inundated along this reach did not change appreciably between the frequent and infrequent events, with the width of flooding averaging about 430 m to 550 m. The one exception, however, was at Structure No. 4 (refer to Figure 2.4). Here the 1:100 year flood line was approximately 60 m wider than that computed for the 1:20 year event. The maximum flow velocity was estimated to be in the order of 0.6 m/sec.

The flooding condition at this site is attributed to the volume of runoff from the upper Humber River catchment area. Ice jams were not found to be a potential hazard.

iv) Damage Centre No. 4 : Governors Point

This site, as shown on Figure 2.5 includes a number of dwellings located in close proximity to Governors Point. In total, four residential structures were found to be flood susceptible under the 1:100 year upper 95% confidence level. This number is reduced to two for the 1:100 year mean. No structures were found to be flood susceptible under the 1:20 year event. No transportation routes were found to be flood susceptible.

The limits of flooding for the 1:20, 1:100 and 1:100 upper 95% confidence level are shown on Figure 2.5. As noted, the width of flooding at Structure Nos. 1 and 2 increased approximately 50 metres between the 1:20 and 1:100 year events. At Structures 3 and 4 the increase was more gradual, being in the order of 10 metres. The average flow velocity was 0.6 m/sec.

2.3.2 Existing Environment

i) Physiography

The study area is located within the physiographic region referred to as The Grand Lake Lowlands (28). This area is comprised of a large northeast-southwest valley (15).

The surficial geology of the Humber River and Steady Brook valleys includes bedrock outcropping, glacial tills and sand and gravel. Exposed bedrock was frequently observed throughout the study area in the form of rock plains, knolls and ridges. In some areas the rock is covered by a thin veneer of soil or is concealed by scrubby vegetation.

The glacial tills found throughout the area exhibit considerable variability in thickness including thin surficial veneers and as more extensive moraine deposits. The composition of the till closely refects the lithology of the underlying bedrock material. Consequently, the tills within the Humber River and Steady Brook valleys are comprised of red clayey silt derived from the underlying red siltstone.

The sand and gravel deposits are outwash and fluvial in origin and are generally confined to the immediate area of the Humber River. Additional buried deposits of sand and gravel occur at various points interstratified within the glacial till deposits.

The soils within the study area are not highly suitable for agriculture due to excessive soil moisture, adverse relief such as steepness, stoniness and shallowness to bedrock. Consequently the land has been cleared in scattered locations primarily for residential dwellings.

ii) Forest Cover

The study area is located mainly within the Humber River valley with a small portion within the Steady Brook valley (see Figure 1.2). This area is within the Boreal Forest Region of Canada. The valley systems are largely in an undisturbed state with a scattering of residentiual buildings located along the south bank of the Humber River and within the Community of Steady Brook.

The forest cover is fairly homogeneous which is characterized by the dominant species; White Spruce, Black Spruce, Balsam Fir in association with Tamarack, White Pine, White Birch, Yellow Birch, Trembling Aspen and Balsam Poplar. The trees are generally mature and healthy within the densest forest cover which generally occurs where the glacial till is the thickest over the bedrock. Sparse forest cover is found in scattered pockets due to thin veneer till soils and exposed bedrock.

Along the river banks, the vegetation is sparse due to rocky soils and exposed bedrock. Tree cover in this area includes poplars and birch and other weedy species.

iii) Aquatic Environment

Information regarding the aquatic environment of the Humber River and Steady Brook is incomplete. However, from available data the Humber River is a wide and slow-moving stream, with rapids at some locations during low flow periods. The bottom materials are generally large rocks, gravel and sand. The water quality appears to be very good. Fish species found within the watercourse include Eastern Brook Trout, Arctic Char, Landlock Salmon and possibly running Smelt.

Steady Brook is a smaller watercourse that has a faster flow than the Humber River. The bottom material includes large boulders, rocks and gravel. The water quality is very good and it is expected that the stream supports a coldwater fisheries.

iv) Social

The social environment within the study area is comprised of residential homes located in Steady Brook and scattered along the south bank of the Humber River to Governors Point at the outlet of Deer Lake. The Trans

Canada Highway and rail line follow along the south side of the river. This provides a major transportation corridor between Corner Brook and St. John's. All forms of development are located on the north side of the highway or just adjacent to the road on the south side.

Residents in this area primarily work in Corner Brook. Within the study area there is little commercial activity. Each residential dwelling has a septic system and the community water supply is upstream from Steady Brook.

2.4 Field Investigations

2.4.1 General

A field program was undertaken to collect additional data for each Damage Centre. The field program consisted of interviews, field reconnaissance and physical field surveys to identify and confirm the following factors:

1. The hydrologic and hydraulic characteristics of the flood prone reaches
2. To inventory and classify flood prone areas and structures
3. To conduct a field examination of geomorphological processes
4. To examine and document any potentially environmentally sensitive areas
5. Obtain local opinions by means of interviews and questionnaires as to the history of flood damages in the area, and potential causes and solutions
6. Obtain regionalized data related to economic value of development
7. To survey potential alignments of possible remedial schemes (i.e. earth berms, dykes, roadways, etc.). This information was also applied in the definition of flood depths and estimates of construction material quantities
8. To survey the first floor elevations of flood susceptible structures for implementation in estimating flood damages
9. Obtain photographic documentation of erosion areas, flood susceptible reaches and structures in the Steady Brook area.

The field program was initiated on June 25, 1985. The results of the program are briefly summarized in the following sections.

2.4.2 Physical Field Surveys

The physical surveys carried out as part of the field program involved primarily the collection of structure first floor elevations and topographic information within the flood risk area. Cross-section profiles were obtained where potential structural remedial works such as berms, etc. could be constructed. Additional cross-sectional data was obtained through utilization of previous surveys (8, 21, 22) on the watershed to supplement the present investigations. The complete inventory of cross-sections, including location and extent, is summarized in Appendix A.

A comparison of the field surveys to the existing 1:2500 scale mapping confirmed that the mapping accuracy met Federal standards for production of topographic maps under the CNFDRP.

2.4.3 Interviews and Questionnaires

As part of the field reconnaissance, interviews were conducted with local land owners and interested parties.

The objectives of the interviews were to collect information relating to land use, property value, structural types and a description and value of contents. As a secondary objective, the interviews allowed the opportunity to discuss historical flood conditions in the area. Social implications of proposed remedial measures and factors contributing to flooding in the study reaches were also discussed during the interviews.

All 37 residences within the flood prone areas were visited with questionnaires distributed in the field. All landowners were requested to complete a questionnaire at the time of interview or, alternatively, at their convenience. Questionnaires not completed during the interviews (i.e. where landowners were unavailable for comment) were requested to be returned by mail. The form of the questionnaire is given in Table A.1, found in Appendix A.

A total of 27 property owners were interviewed in the field, while only 13 landowners completed a questionnaire (all in the Community of Steady Brook). This total interview ratio is fairly good (73% of all residents visited) while the return ratio of completed questionnaires was somewhat disappointing (only a 35% respondent return). However, in considering the Community of Steady Brook independently, 72% of those residents approached completed the questionnaire.

During the interviews, most homeowners talked openly about their lands and the implications of flooding on their properties. The opinion of the residents were also invaluable with respect to potential remedial solutions for control of flooding in the study area.

Table 2.1 summarizes the results of the completed questionnaires. Estimates of economic damages as submitted by the local residents in their completed questionnaires have been included in the data presented. Due to the confidentiality of the data submitted, an arbitrary numbering system to identify each of the properties has been adopted for presentation herein.

Many residents were of the opinion that berms or dykes would not be a complete solution to the flooding problem. Some residents believe that often flooding is a result of surcharging of the groundwater table in conjunction with high flows on the Humber River. In fact, basement flooding was the most frequently reported problem and often occurs in the absence of surface flooding.

About 50% of the residences surveyed (see Table 2.1) were found to have finished basements. The quality and contents of the homes appear to vary greatly throughout the study area.

Most people were of the opinion that revisions to the operational policies of Grand Lake at the Deer Lake Power Company dam would help to improve the flooding condition along the Humber River.

The results of the interviews and questionnaires processed were incorporated into the development of stage-damage relationships for the area, and this is discussed in Section 2.5.

2.5 Preliminary Assessment of Flood Damages

2.5.1 Methodology

The damages and cost-benefit analyses were undertaken according to procedures outlined by Environment Canada (12).

Mean annual flood damages were estimated for each of the four damage centres discussed in Section 2.2. It was found that a flood frequency - water level relationship could be derived and applied to each damage centre.

Topographic surveys were undertaken to relate the first floor, ground and lowest water entry elevations of each flood susceptible structure to geodetic datum. These elevations were then related to the various design flood levels for derivation of potential flood stage versus damage estimates. The results of these surveys are tabulated in Appendix A.

A photographic inventory of flood prone structures was also undertaken at the time of the field survey to provide for the classification and identification of each structure in the damage computation procedure. Estimates of the value and the flood damage to contents were obtained through questionnaires and interviews. Real estate market values of the properties, land costs and construction indices were obtained through discussions with representatives of several individuals and agencies.

Additional details of the assessment of flood damages can be found in Appendix B.

2.5.2 Composite Stage-Damage Curves

Flood damage estimates for a structure and its contents were determined from generalized curves relating the depth of flooding around a structure to the resulting damage value. The curves which were utilized to assess the flood damage for different classes of structures within the major groups of residential and commercial were based on the draft report entitled, "Residential Depth-Damage Curve Development Study" prepared by Paragon in 1985 (24). These curves, along with additional information on the methodology applied in their application, can be found in Appendix B.

The flood damages discussed in the Paragon report were based on quantitative data collected for Southern Ontario. Therefore, an assessment of the regional economic differences in real estate between Ontario and that of Newfoundland was investigated. Based on a survey of house sale prices in Steady Brook, discussions with real estate agents, and a comprehensive assessment of the responses received from the damage questionnaires, it was concluded that adjustments to the structure damage curves were not warranted. An upward adjustment factor of 1.68 was, however, required for the content damage to account for regional economic differences (see Appendix B.1.4).

In addition to direct damages which include losses such as physical damage to an existing structure (e.g. building, shed, etc) and its contents, indirect flood damages can also occur. Indirect flood damages are costs or losses which are not the result of direct physical contact with water. Indirect damages include; disruption of residential living conditions, loss of sales and production to business firms, loss of wages, increased transportation costs and lost travel times, etc. For the proposed study, the indirect damages were assumed to be 30% of the direct damages. Further details as to derivation of indirect damages are provided in Appendix B.

2.5.3 Damage Elevation Curves and Average Annual Damages

A damage-elevation curve was established for each of the four Flood Damage Centres (see Figure 2.6). This curve was developed from both the water level frequency data, which is interpreted from the results of the hydrologic and hydraulic investigations and the damage elevation curves. Both sets of data are depicted in Figure 2.6. Combining this information as per Figure 2.6, damage frequency curves are developed from which expected flood damage values can be established for any given design storm event at each of the four Damage Centres.

The U.S. Army Corps of Engineers Expected Annual Flood Damage Model, or EAD (33) was utilized in order to determine the weighted average annual flood damages for each flood mitigative scheme assessed. The average annual flood damage at each Damage Centre was computed by integrating the stage-frequency relationship for each Damage Centre. This procedure weights damages associated with the more frequent events more heavily. The area under the curves equals the expected annual flood damage, or in other words, is a probability weighted damage value. A summary of the expected average annual damages computed for each of the Flood Damage Centres is given in Table 2.2. Further details on the development of the expected average annual damages for the study reaches can be found in Appendix B.

TABLE 2.1

Summary of Damage Questionnaires

Structure Classification (1) Structure Group	Type of Structure	No. of Respondents by Structure Type	Relative Degree of Occurrence to Basement Flooding		Relative Degree of Occurrence to Property Flooding	Total ($) Estimated Damages	Other Factors Affecting Flooding
			With Sumps	Without Sumps			
1	One storey no basement	3	N/A	N/A	1976-1979	- no estimate made - some damage occurs	- Fast flowing water
2	One storey with basement	7	Very frequent to annual flooding	No flooding to once every other year	No flooding to annual flooding	- ranges from no damage up to $10,000	- Fast water - Ice jams at swimming pool - Groundwater flooding - Basements
4	Two storey with basement	3	None to almost annually	Four times	None to almost annually	- $15,000 to $25,000	- Groundwater associated with Bowater/ Kruger spilling of water
		13					

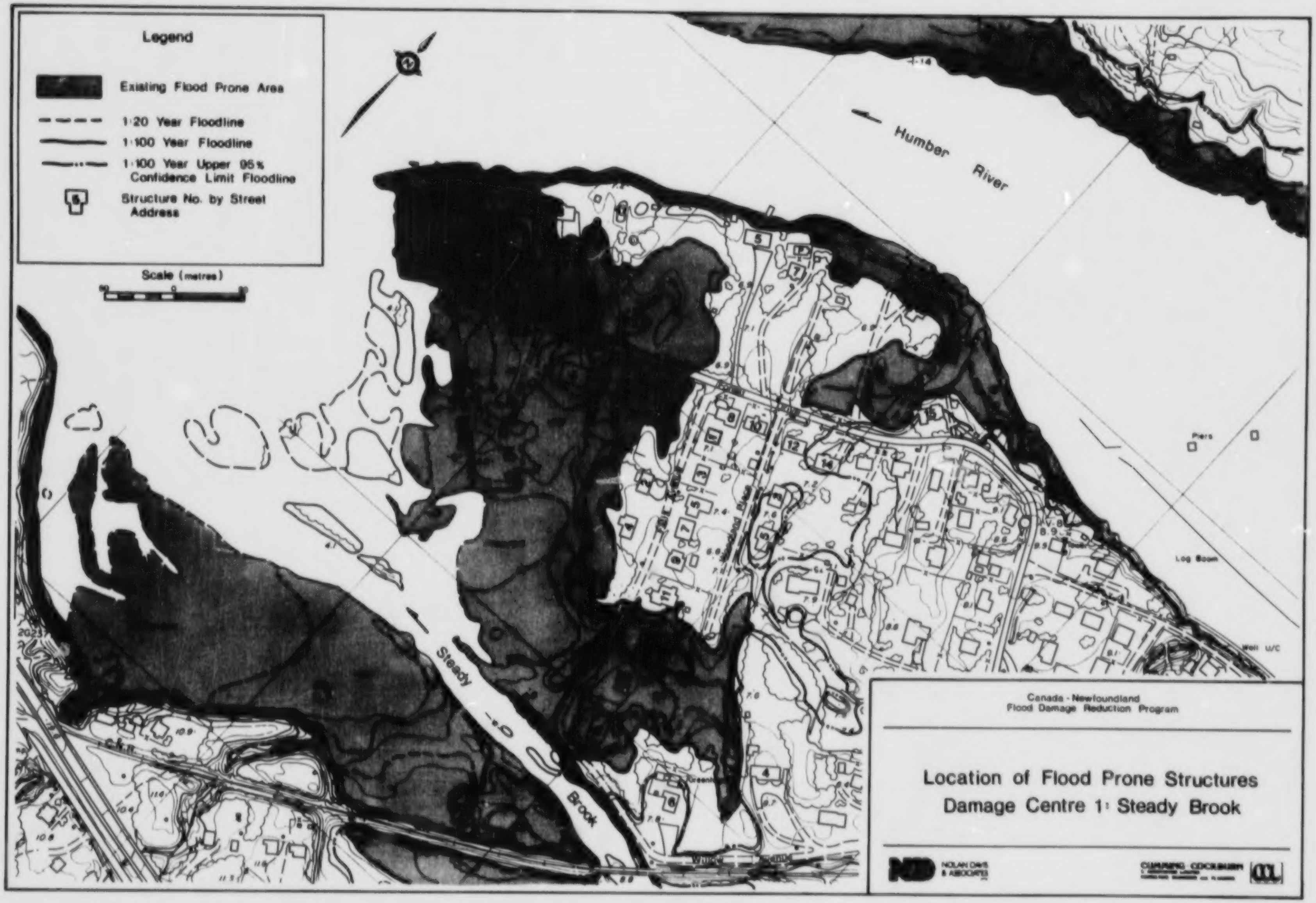
(1) See also Appendix B for classification method (24)

TABLE 2.2

Summary of Existing Expected Damage Estimates

Damage Centre No.	Location	Average Annual Damage ($) Mean	Average Annual Damage ($) +95% C.L.	Total Present Value (1) Damage ($) Mean	Total Present Value (1) Damage ($) +95% C.L.
1	Community of Steady Brook	9,010	24,760	89,300	245,500
2	Russell	1,940	5,890	19,200	58,400
3	Harrison	5,140	9,640	51,000	95,600
4	Governors Point	840	2,320	8,300	23,000
	TOTAL	$16,930	$42,610	$167,800	$422,500

(1) Based on an effective discount rate of 10% and project life of 50 years


Legend
Existing Flood Prone Area
1:20 Year Floodline
1:100 Year Floodline
1:100 Year Upper 95% Confidence Limit Floodline
Structure No. by Street Address
Scale (metres)
Humber River
Steady Brook
Piers
Log Boom
C.N.R.

Canada - Newfoundland
Flood Damage Reduction Program

Location of Flood Prone Structures
Damage Centre 1: Steady Brook

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CUMMING COCKBURN

Figure 2.1

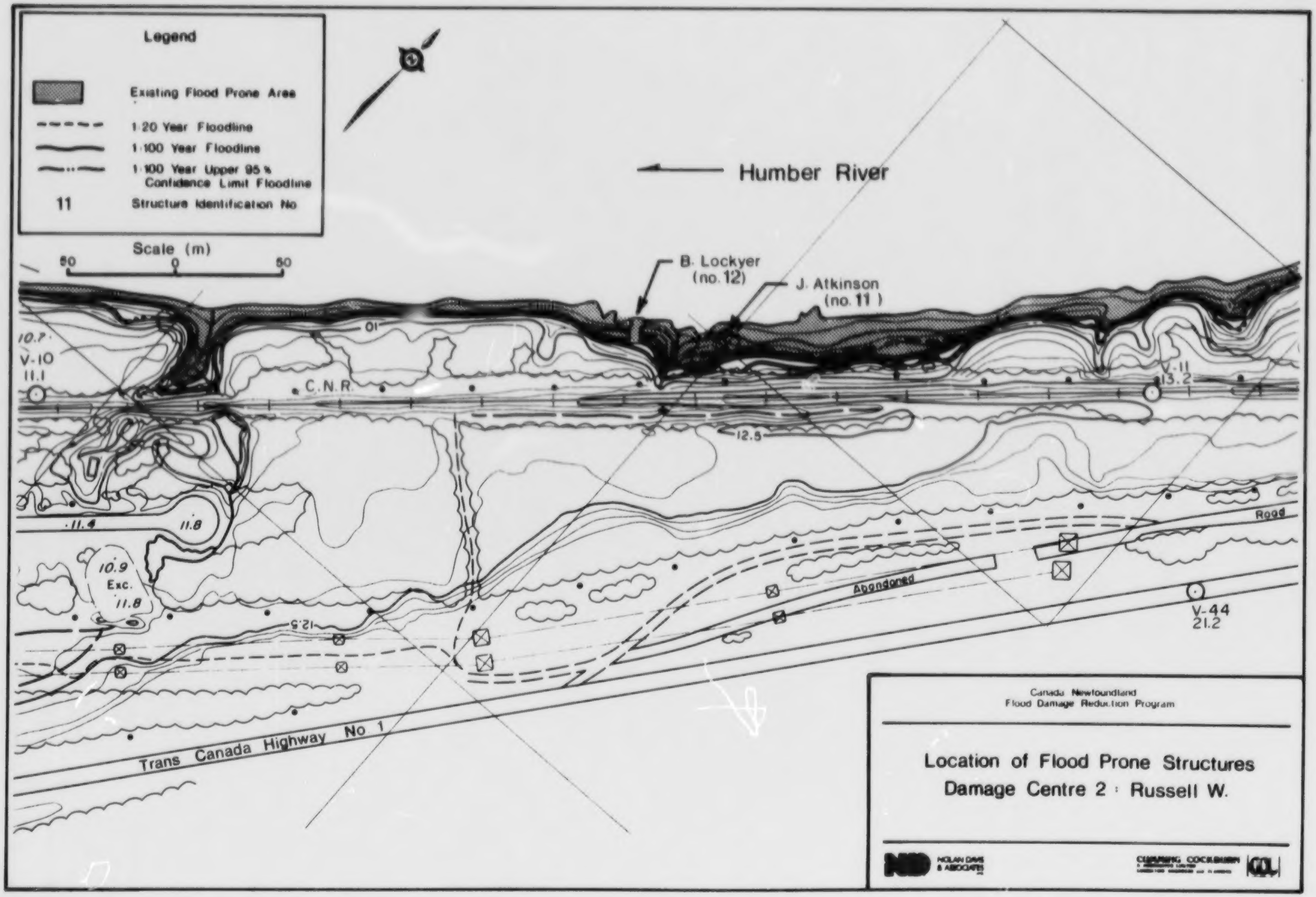
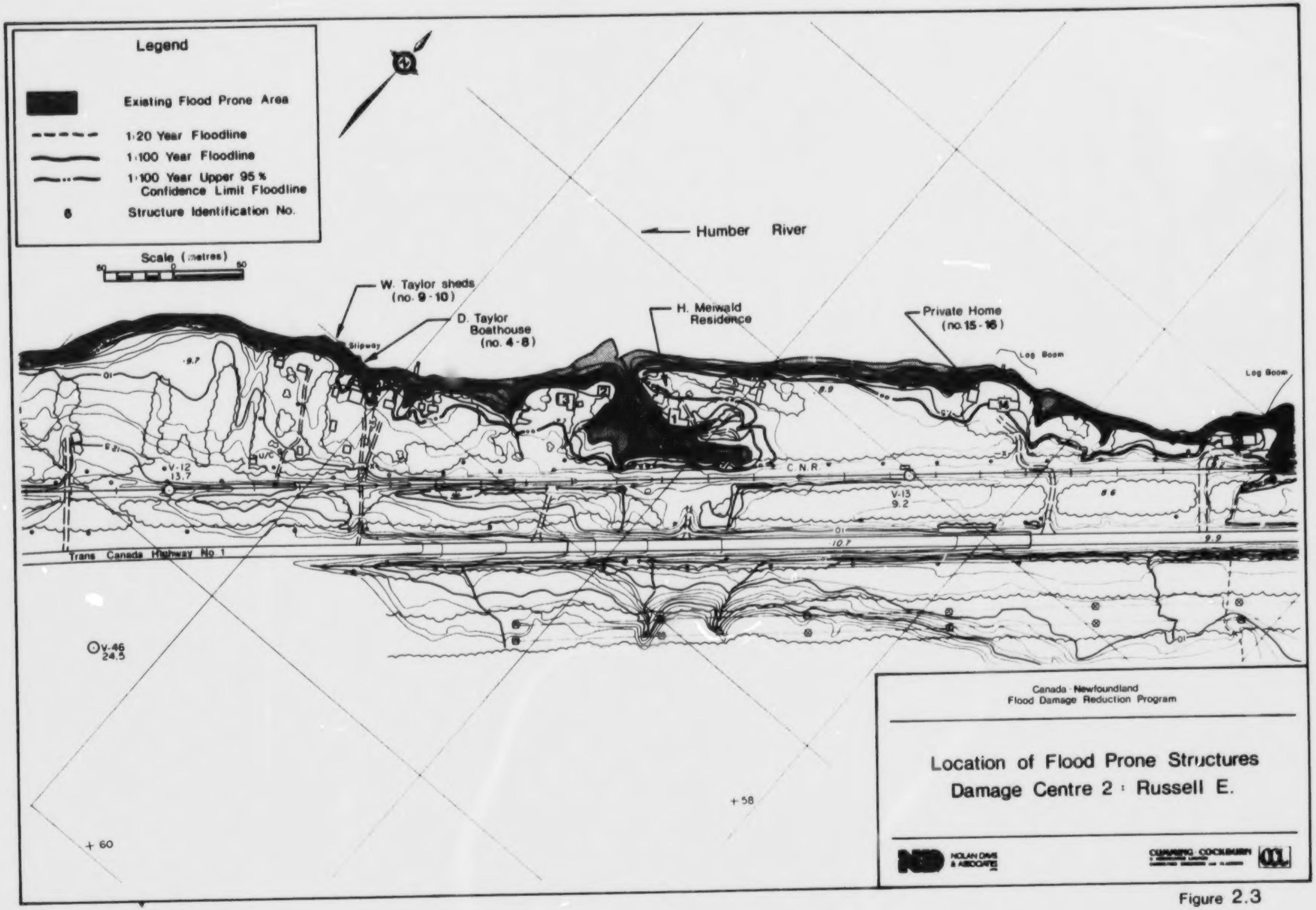

Legend
Existing Flood Prone Area
1:20 Year Floodline
1:100 Year Floodline
1:100 Year Upper 95 % Confidence Limit Floodline
11 Structure Identification No
Scale (m)
50
0
50
Humber River
B. Lockyer (no. 12)
J. Atkinson (no. 11)
C.N.R.
V-10
11.1
10.7
V-11
13.2
V-44
21.2
10
12.5
11.4
11.8
10.9
Exc.
11.8
12.5
Road
Abandoned
Trans Canada Highway No 1
Canada Newfoundland Flood Damage Reduction Program
Location of Flood Prone Structures Damage Centre 2 : Russell W.
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN
CCL

Figure 2.2


Legend
Existing Flood Prone Area
1:20 Year Floodline
1:100 Year Floodline
1:100 Year Upper 95 % Confidence Limit Floodline
6 Structure Identification No.
Scale (metres)
50
0
50
Humber River
W. Taylor sheds (no. 9 - 10)
Slipway
D. Taylor Boathouse (no. 4 - 8)
H. Meiwald Residence
Private Home (no. 15 - 16)
Log Boom
Log Boom
C.N.R.
V-12 13.7
V-13 9.2
V-46 24.5
Trans Canada Highway No 1
+ 58
+ 60
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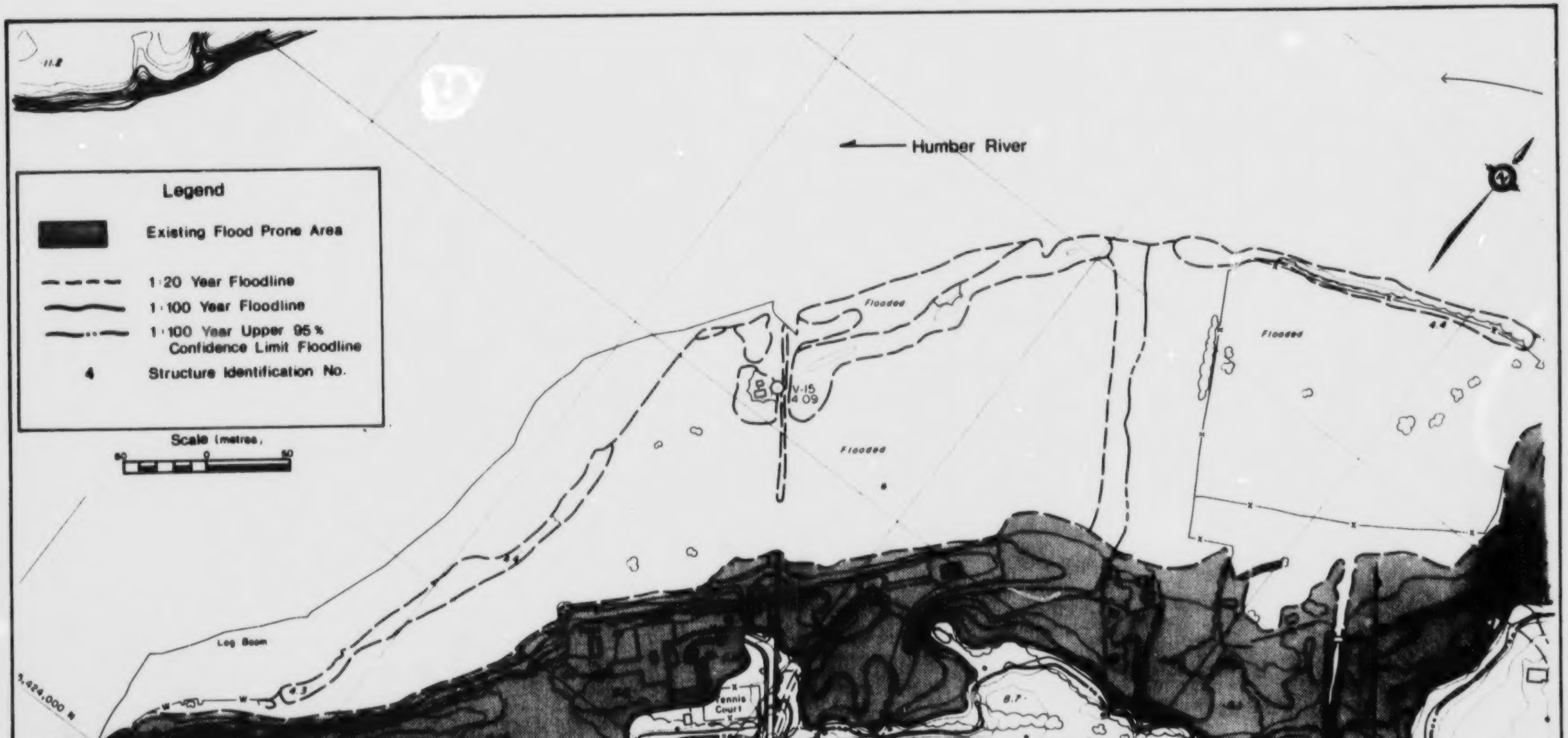
Canada - Newfoundland
Flood Damage Reduction Program

Location of Flood Prone Structures
Damage Centre 2 : Russell E.

Figure 2.3


Humber River
Legend
Existing Flood Prone Area
1:20 Year Floodline
1:100 Year Floodline
1:100 Year Upper 95%
Confidence Limit Floodline
4 Structure Identification No.
Scale (metres)
50
0
50
Flooded
Flooded
Flooded
V-15
4.09
Log Boom
5,424,000 N
Tennis Court
C.N.R.
Trans Canada Highway No. 1
7.5
9.4
8.7
4.4
11.8

Canada Newfoundland
Flood Damage Reduction Program

Location of Flood Prone Structures
Damage Centre 3: Harrison

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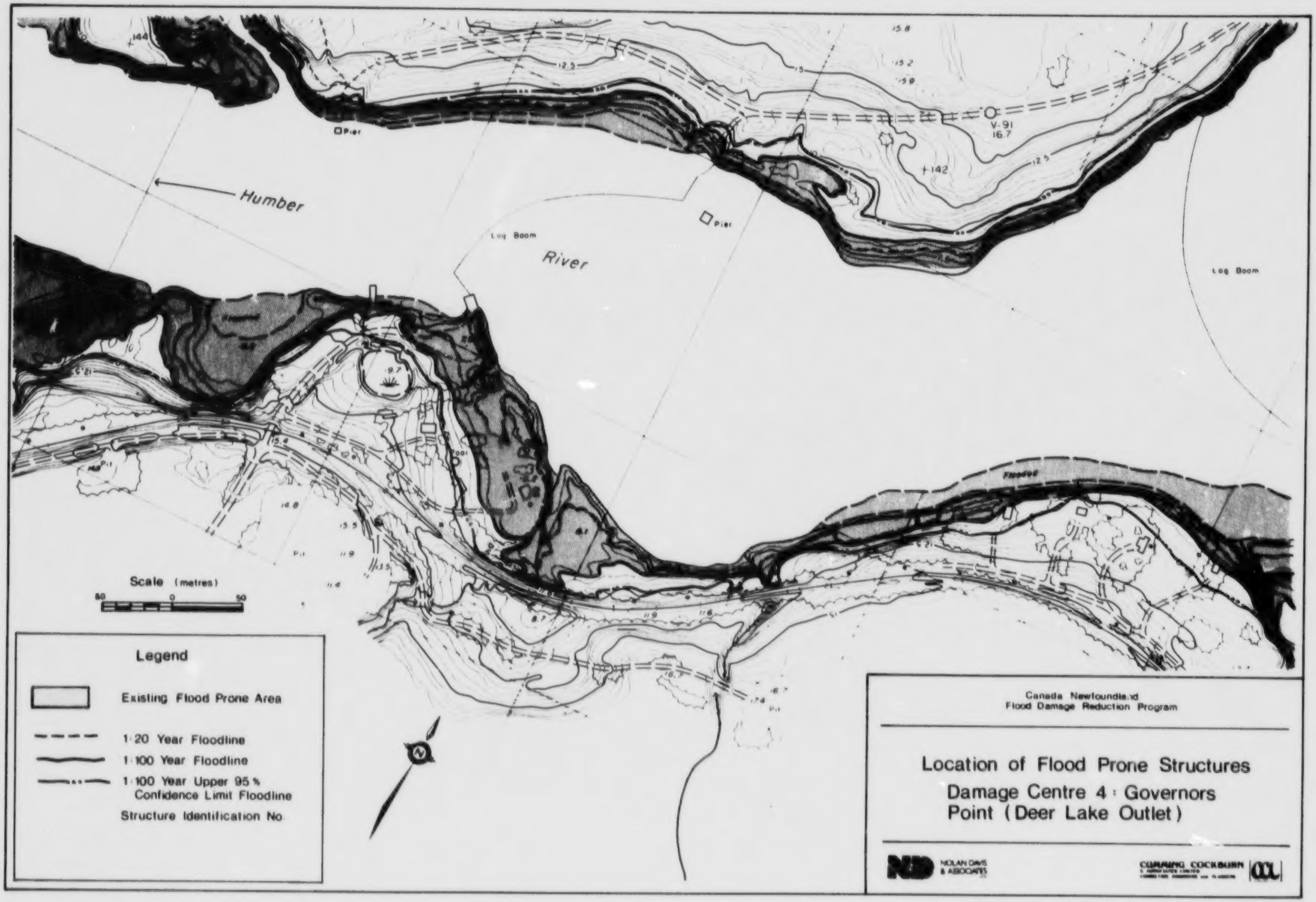
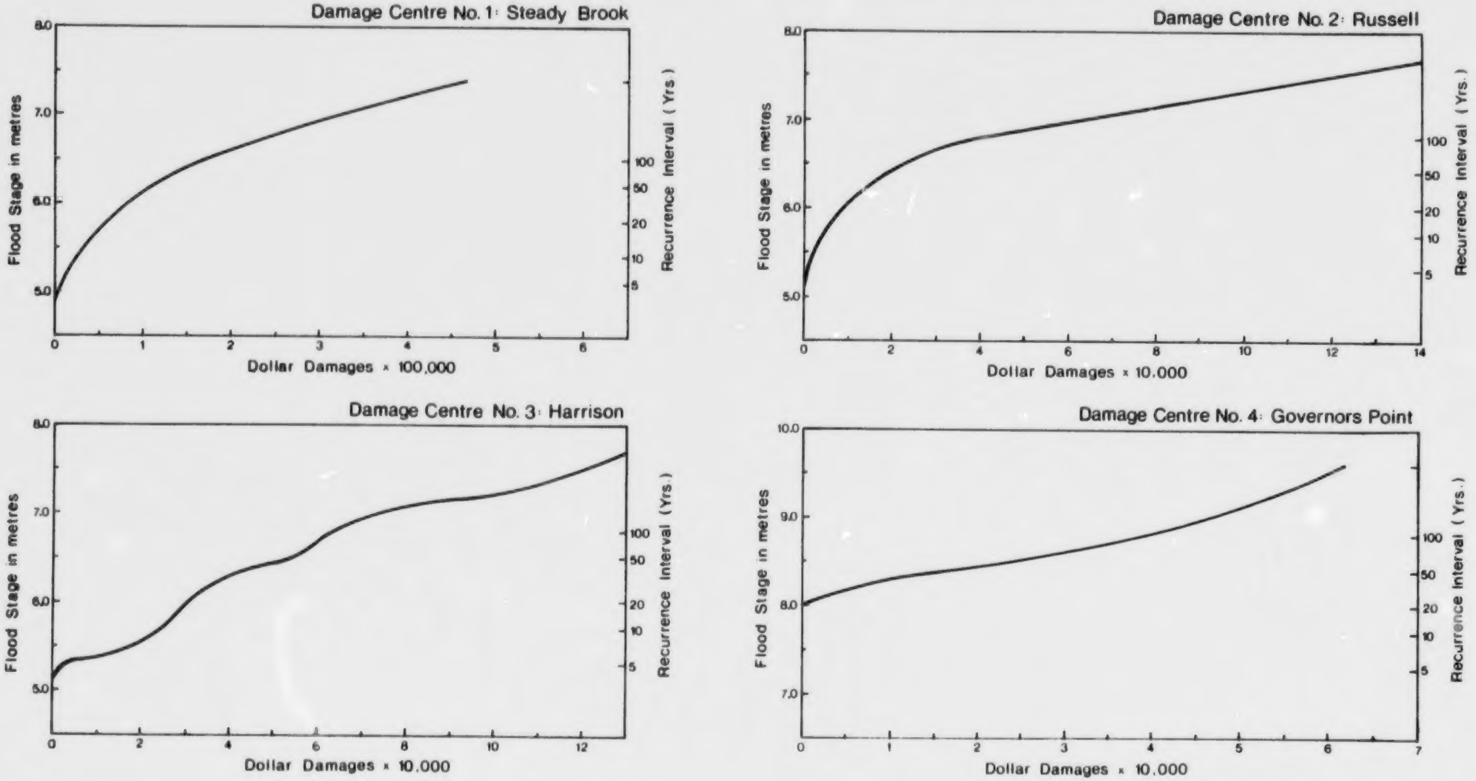
Figure 2.4


Humber
River
Log Boom
Log Boom
Pier
Pier
V-91
16.7
142
144
Scale (metres)
50
0
50
Legend
Existing Flood Prone Area
1:20 Year Floodline
1:100 Year Floodline
1:100 Year Upper 95 %
Confidence Limit Floodline
Structure Identification No.
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

Canada Newfoundland
Flood Damage Reduction Program

Location of Flood Prone Structures
Damage Centre 4 : Governors Point (Deer Lake Outlet)

Figure 2.5



Notes:

1. Damages based on June, 1985 dollar value
2. Flood stage information from the Hydrotechnical Study of the Steady Brook Area. Nolan, Davis & Cumming Cockburn, October, 1984
3. Recurrence Intervals for mean discharge events

Canada Newfoundland
Flood Damage Reduction Program

Composite Stage-Damage Curves

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Figure 2.6

3.0 PRELIMINARY ASSESSMENT OF REMEDIAL MEASURES

3.1 General

The policies for floodplain management adopted by the Province were designed to fulfill the following objectives:

- Prevention of loss of life;
- Minimization of property damage and social disruption; and
- Encouragement of a coordinated approach to the use of land and management of water.

Urban development within the Communities of Steady Brook, Russell, Harrison, and Governors Point has been located in close proximity to Steady Brook and the Humber River, resulting in a high flood potential at each of these communities. Consideration must, therefore, be given to the implementation of a floodplain management policy to control future development within the area and to the possible implementation of structural flood control schemes in order to meet the objectives listed above.

The following sections of the report describe the alternative flood mitigative control schemes; including maintenance of the status quo, "Non-structural Approach", and possible "Structural Measures". Potential impacts to the social and natural environments are also identified for each scheme.

3.2 "Status Quo"

This assumes the continuation of the current conditions. The flood hazard which presently exists within the study area would remain unchanged. No additional structural or non-structural schemes would be introduced for flood mitigation. We assume that floodplain zoning previously recommended would continue to be utilized (Cumming-Cockburn, 1984).

At the present time, no preventative action has been taken to minimize the flooding potential. Although the area has been designated under the FDR program, if continued development occurs within the four Damage Centres, it would be safe to assume that the magnitude and frequency of the flooding presently being experienced could increase somewhat with time, leading to increased flood losses.

The maintenance of the status quo assumes that a form of compensation for flood losses could be provided. As such, this option warranted further consideration and was carried over to the Phase II investigations of the study.

3.3 Non-structural Measures

3.3.1 Flood Forecasting/Warning System

i) Engineering

In many flood prone areas, it is frequently possible to design and set up a flood forecasting/warning system to help reduce flood damages during periods of high runoff. Upon receiving the forecast that a flood is imminent, steps can be taken to reduce the damages associated with flooding. These can include such measures as sandbagging around structures to stop floodwater at low points and window sills, etc., and transferring the flood prone contents of the structures to safe areas. Another measure which could be taken to reduce flood damages would be to spill excess flows from Grand Lake prior to the occurrence of the forecasted peak flow in order to obtain enough storage volume to contain the runoff during the peak periods.

Due to the time required to implement flood damage reducing measures, streamflow forecasting is almost always associated with an element of urgency. However, the usefulness and practicality of flood forecasting is dependent on both the accuracy and timing of and response to a given forecast. For example, the value of an accurate forecast reduces significantly with time until its value approaches zero at the time of the event. Therefore, an important feature of a flood forecasting system is the ability to minimize the time of forecast preparation and maximize the warning time for an accurate forecast. Computer simulation techniques are frequently used for flood forecasting as they represent a high speed and flexible tool. If there are reservoirs within the hydrologic system under analysis, computer simulation is preferred as it permits testing of several operating procedures in order to determine which one will give the best results.

For the purposes of generating flood flows in the Humber River system, the SSARR (Streamflow Synthesis and Reservoir Regulation) model was utilized in undertaking recent investigations (7,8,32). The existing SSARR model was utilized in the flood forecast mode in order to examine the feasibility of reducing flood damages by means of flood forecasting. The forecast model must integrate data collection and model the main components affecting flooding. Therefore, due to the complexity of the system, the large storage effects, etc., simplified forecast systems are not considered to be applicable.

In the flood forecasting mode, the computations by the model should be restarted daily or more frequently under rapidly changing conditions. This fact places a great importance on the model to compensate for the effects of initial conditions and to adjust the antecedent computations to the observed initial conditions.

The data presently available to predict hydrologic conditions in the watershed are barely adequate. As the runoff computation is extended into the future, the hydrologic input is composed of forecast values of meteorologic conditions which are also subject to limitations and some inherent inaccuracies. This places great responsibility on the forecaster and the model to be realistic about the compromise between theoretically desirable complexity and computational detail in light of the validity of the hydrologic data available as input. Significant forecast errors would be expected if the existing hydrometeorologic data collection network in the watershed is not significantly upgraded.

When applying the SSARR model in a flood forecast mode to the Humber River system, both long term and short term forecasts would be undertaken. Short term forecasts could be undertaken when a meteorologic forecast predicts abnormally high rainfall activity or a combination of high temperatures, rainfall and a significant snowpack. Long term forecasts could generally be undertaken during the winter months when snow accumulation can result in a significant water equivalent entering the hydrologic regime during the spring freshet. The long-term simulations could also be utilized to assist in the operation of Grand Lake. For example, if long term simulations of the SSARR model indicated that a fairly heavy snowpack existed within the watershed, the operation of Grand Lake could be modified in such a manner as to control more of the runoff during the peak freshet period. Conversely, if the SSARR simulations indicated a relatively light snowpack, the rule curve for the Grand Lake reservoir could be modified in order to reduce the drawdown and possibly avert water shortages and power station shutdowns at a later date. It should be noted that the Deer Lake Power Company (formerly the Bowater Power Company) has been estimating snowpack by relying on several snow survey stations throughout the watershed. However, we believe that the SSARR model is capable of providing more accurate and refined snowpack forecasts than the existing snow survey stations.

Regarding any short term flood forecast, it is important to note that peak flows are a function of many variables including antecedent watershed conditions. Therefore, in order to accurately define the initial conditions prior to a flood event, simulations are usually started several months (up to eight for spring freshet events) prior to the event. The set-up time associated with a simulation of this nature (8 months in duration) is in the order of 2-3 man-days. Because the short term meteorologic forecasts are usually of acceptable accuracy only for a maximum period of approximately 3-4 days, it is imperative to telemeter the data for direct input to the model. Assuming improvements in the meteorologic network, the SSARR model would, in our opinion, provide adequate forecasting results and accuracy for future flood events on the Humber River watershed.

The additional data requirements can be subdivided into meteorologic, hydrometric (both streamflow and water levels) and snow course stations and are described as follows:

Proposed Automatic Meteorological Stations (Precip., Temp.):

- Western End of Grand Lake near T.C.H.
- Near Battle Pond
- North Side of Grand Lake near Glover Island
- At Hinds Brook Power Station
- Near Sheffield Lake at T.C.H.
- Near Birchy Lake

Proposed Streamflow Station:

- Indian Brook Diversion (to Birchy Lake) (i.e reinstate W.S.C. gauge)
- Continuation of existing gauges

Proposed Water Level Recorders (telemetred):

- Outlet of Deer Lake
- West end of Grand Lake
- Outlet of Grand Lake
- Inlet of Deer Lake

Proposed Snow Course Stations:

- Near Gros Morne National Park) all upper
- Near Adies Pond) Humber -
- Near Birchy Lake) telemetred
- Upgrade other stations with regard to frequency and data collection methods, etc.

It is recommended that if a flood forecasting technique is adopted the proposed and existing meteorologic data base be telemetered in real time to a central location. This will be required to improve the utility of the SSARR model in the flood forecast mode. The cost of implementing telemetered data is estimated to be roughly $350,000.

The interactive version of the SSARR model could be adopted and would be beneficial for the purpose of providing flood forecasts for volumes and peak flows. As additional data is collected, the model would be continually refined. The cost of implementing SSARR in the interactive forecast mode is estimated to be $25,000 to $50,000.

The accuracy of the SSARR model in the forecast mode would have to be re-evaluated fully after several (4-5) years of active use of the model in order to allow a full assessment of the implications of forecast errors, etc. Forecast errors which require specific evaluation prior to the implementation of the system include accuracy in predicting rainfall and other meteorological input parameters (both at a point and areally in the watershed) and separation of model input errors and model simulation accuracy.

ii) Benefit Cost Analysis

It is assumed that the maximum possible flood warning benefit would be the protection of the basements of the houses within the flood hazard zone. If damages due to basement flooding are (from surface flow) eliminated, the present value of benefit associated with this alternative would be approximately $63,000. It is estimated that the cost associated with this alternative would be approximately $300,000 - $400,000 and would include the set-up of the model and additional hydrometric and meteorologic stations. It was assumed that the annual forecast costs of providing flood forecasts would be paid from Environment Newfoundland's annual operating costs and would amount to about $10,000 per year for labour and computer charges. In addition, annual maintenance costs for the water level and snow course stations listed previously are estimated to total about $41,000 per year (based on recent experience of Environment Newfoundland).

The total annual operating costs for the flood warning system would, therefore, be on the order of $51,000 per year, corresponding to a present value of $505,700 (assuming a 50 year life and a 10% discount rate). The cost of sandbagging and emergency flood-fighting measures are not included in the cost benefit analysis for the flood forecasting system. Therefore, the present value costs would total roughly $805,700 to $905,700, resulting in a benefit-cost ratio of less than 0.1. It is therefore evident that flood warning would not be a cost-effective means of controlling future flood losses.

Additional benefits might accrue due to increasing efficiency in power production, although an absolute estimation of these benefits is beyond the scope of this investigation.

If the marginal benefits required for a benefit-cost ratio of 1.0 were assumed to be derived from an increase in power production, due to better operating information available from the hydrologic forecast model, then an estimate of the required benefits due to power production can be made. This amounts to additional power revenue requirements of about $85,000 per year. In other words, the benefit of a better forecasting system would be over ten times greater for power production compared to the flood forecasting benefits. Preliminary discussions with the Deer Lake Power Company have indicated that if the forecast system were to result in significantly less spill from Grand Lake, then the additional power revenue could be well in excess of the annual forecast costs. A preliminary examination of spill records for the last 15 years has indicated average spill amounts in excess of 200 million cubic metres per year from the Grand Lake Dam. However, it is not possible to make accurate estimates of the value of water spilled or of the amount of revenue recovered with a better forecast system at the present time.

iii) Environmental Analysis

In our opinion, this scheme will not change the existing conditions of the social or natural environments.

3.3.2 Modifications to Upstream Reservoir Operations

i) Engineering

At present, the only regulated reservoir which has a significant impact on the hydrologic response downstream of Deer Lake is Grand Lake. Currently, this reservoir is primarily utilized for hydroelectric power generation by the Deer Lake Power Company (formerly the Bowater Power Company). As such, mitigation of downstream flooding is sometimes a by-product of the present operating procedures.

It has been postulated by others that if Grand Lake was operated as a flood control reservoir, flooding in many instances could be alleviated downstream of Deer Lake. However, due to the fact that a significant portion of the total watershed draining to Deer Lake is uncontrolled (e.g. Upper Humber River), it is felt that operating Grand Lake as a flood control reservoir can only be accomplished in conjunction with a flood forecasting model as discussed in Section 3.3.1. By utilizing a flood forecasting model, the flows out of Grand Lake could be reduced (and the available storage utilized) when it appears a flood is imminent.

In order to assess the feasibility and effectiveness of utilizing computer simulation flood forecasting techniques in conjunction with revised operating procedures, the June 1984 flood event was selected for analysis purposes. This event was selected as it is one of the few recent historic flood events of significant magnitude for which sufficient hydrometric and meteorologic data exists for hydrologic modelling purposes.

The June 1984 flood event was predominantly rainfall generated and resulted in flows throughout the study reach equivalent to about a 1:10 year flood level.

It is of interest to note that although this event resulted in a 1:10 year flood event within the study area, the contribution from the Upper

Humber River was very significant. For example, the frequency analysis undertaken for the Upper Humber River (7) indicates that the peak flow recorded at the outlet of the Humber River during the June 1984 flood event was in excess of the 1:100 year event. It is somewhat difficult to determine the recurrence interval associated with the peak flows out of Grand Lake due to the high degree of regulation. However, it is evident by reviewing the hydrometric records that excess flows from Grand Lake were detained and then released after the peak discharge from the Upper Humber had passed. Utilizing the existing SSARR model and the recorded hydrometric data, a scenario can be analysed in which peak discharges from Grand Lake and the upper Humber River occur simultaneously. Results of this simulation indicate that peak discharges throughout the study reach would have been in excess of the 1:100 year event. If it is assumed that the event occurred simultaneously over the entire Humber River watershed, it can, therefore, be concluded that the operational procedure adopted for Grand Lake during the June 1984 flood event very likely significantly reduced peak discharges downstream.

An analysis was also undertaken in which it was assumed that a flood forecast model had been implemented. Various operational scenarios for Grand Lake were then evaluated. Due to the fact that this event was a predominantly rainfall generated flood, the maximum amount of warning possible would be about 3 to 4 days (see Section 3.3.1). Therefore, it may have been possible to modify the operational procedures of Grand Lake in order to reduce inflows to Deer Lake. For these hypothetical simulations, it was assumed that all discharges from Grand Lake were reduced to zero on June 1, June 2, June 3 and June 4 respectively. For comparison purposes, the outflow hydrographs from Deer Lake are presented on Figure 3.1 as well as the simulated historic runoff sequence which was actually experienced. It is evident from this comparison that if an accurate forecast could have been obtained approximately four days prior to the June, 1984 flood event, the peak flows downstream of Deer Lake could have been reduced 26%. As one would intuitively expect, forecasts received at later dates result in lesser potential reductions to downstream flows.

Although flood forecasting and modified operation of Grand Lake would appear to represent a potential for significant reductions in peak flows during flood events, it is important to consider and analyse the consequences of operating Grand Lake in this manner. Two of the most significant consequences during periods of high flows are the high lake levels which would be attained in Grand Lake and the power losses associated with the generating station being inoperative. For example, at present the maximum allowable water level in Grand Lake is 379.0 ft. If during the June 1984 flood event the outlets from Grand Lake were closed on June 1, it would have been necessary to draw down the reservoir approximately 1.2 ft. in order to avoid overtopping the dam. Furthermore, retaining all water within Grand Lake (assuming a 4-day forecast) to reduce downstream flood damages would result in the Power Station being inoperative for a long time period (up to 8 days). The simulations also indicated that there is not sufficient warning time to draw down Grand Lake to create additional flood storage prior to the occurrence of the peak flow. Operating the power dam in this manner not only would result in loss of significant power revenues (i.e. the loss of revenue would be greater than flood damages), but is very unlikely to occur since the Deer Lake Power Company has the right to use the water in the system.

ii) Benefit Cost Analysis

It is evident from the simulations of the June 1984 flood event that a revised operating procedure for Grand Lake could reduce downstream flood damages. The resulting discharges from the revised operating procedures for Grand Lake were then input to the HEC-2 backwater model derived for the study area (8). Resultant flood levels under the proposed scheme were derived and compared to the flood levels under existing conditions. The reduction in flood levels and associated damages represented the mean annual benefit under the scheme.

Assuming a reduction in peak flows of 26% is possible for all flood events, the corresponding mean annual benefit would be about $16,320, due to control of the more frequent flood damages. (Additional details pertaining to the evaluation of mean annual benefits can be found in Appendix B of the report.)

However, as previously discussed, this alternative must be implemented in conjunction with a forecast model such as that described in Section 3.3.1. The present value of the annual benefit is estimated to be $161,800 (50 year life and 10% discount rate) resulting in a benefit-cost ratio of less than 0.18. (A very significant cost would also be associated with shutting down the power station for the duration of the flood event, likely an order of magnitude higher than the flood costs). Therefore, while refinements to the cost-benefit analysis are required to account for possible changes in power production, we are of the opinion that this alternative is infeasible due to the high operating costs for the flood forecasting system (i.e. strictly as a flood reduction measure).

iii) Environmental Analysis

The proposed modifications to the upstream reservoir, Grand Lake, operations would result in a necessary drawdown of the reservoir of at least 1.2 ft. The available data of the environmental condition of the lake is somewhat limited and it is, therefore, difficult to make accurate prediction of the long-term impacts due to the modification to the operation procedures of the reservoir. However, the present rule curve indicates that the level of Grand Lake changes as much as 7.2 ft. over an average year. It is, therefore, unlikely that the proposed alteration will have any additional significant impact on the existing conditions of the aquatic environment of Grand Lake. However, much more investigation is required into the potential impacts before this scheme can be recommended.

3.3.3 Property Acquisition

i) General

One alternative for the alleviation of flood hazards within the study area would be to purchase all the properties located within the floodplain. For this investigation two flood levels were considered, namely the 1:100 year mean and the 1:100 year upper 95% confidence level. The 1:100 mean level was considered to be the most reasonable level while the upper 95% was considered for the purpose of sensitivity testing. The area inundated for each event and the location of the affected structures are delineated on Figures 2.1 through 2.5 for the communities of Steady Brook, Russell, Harrison, and Governors Point respectively. The number of structures which would require purchasing for each flood condition is summarized in Table 3.1.

ii) Benefit Cost Analysis

To provide complete flood protection with this option, the purchasing of all properties within the designated flood hazard areas would be required. To determine the economic value of the affected properties, discussions were held with local real estate agents (Thorne Real Estate, Corner Brook (30)). Based on those discussions, the following general conclusions are established:

- For Steady Brook the average price for a three bedroom bungalow is about $55,000 to $60,000. For split levels the market value is about $65,000 to $75,000.
- In Harrison, the average home prices are approximately $30,000 less than those in Steady Brook.
- In the Deer Lake area, the average house price is approximately $20,000 less than in Steady Brook.

The purchasing of properties can be an effective method of providing flood proofing protection provided the number of affected structures is not significant. As evident in Table 3.1 such is not the case for the study. The estimated cost for the purchasing of all properties within the study area (includes all four damage centres) is about $1,650,000 and approximately $3,230,000 for the 1:100 year mean and upper 95% confidence level respectively.

The Benefit Cost analysis found that the cost for property acquisition far exceeded the resultant benefits. The benefit/cost ratios were computed to be 0.19 and 0.25 for the 1:100 year mean and upper 95% confidence level respectively.

iii) Environmental Analysis

Purchasing property within the study area would represent a major disruption to the social environment of the local community. Property acquisition would change the community matrix and be extremely costly. From this viewpoint, this alternative is not considered feasible.

3.3.4 Floodplain Management Policy

i) Engineering

The adoption of floodplain management policies can be an effective method of providing flood hazard protection for all future development which may occur within the developing communities. It does not, however, provide flood protection for any development which already has occurred within a flood susceptible area.

Implementation of a floodplain management policy which prohibits any future development or redevelopment within the designated flood hazard area represents the most severe application of the policy. An option which provides flood protection without totally freezing all lands within the 1:100 year floodplain involves the adoption of the two zone floodway-flood fringe concept.

The floodway is the central portion of the floodplain which is reserved for the passage of flood flows. The flood fringe is the area at the extremities of the floodplain where the velocity of flow is low and the depth is shallow. Additional development might be permitted in the flood fringe areas depending on the degree of hazard and the implementation of flood proofing measures to protect these areas.

The 1:20 and 1:100 year flood limits have been designated by the Province of Newfoundland and the Government of Canada in Steady Brook.

The adoption of a floodplain management policy by the Community is recommended for the study area. However, as it will only provide protection for future development, it's implementation is not considered to be the ultimate solution to the flood hazards which presently exist.

ii) Benefit Cost Analysis

No benefit cost analysis can be undertaken for this scheme.

iii) Environmental Analysis

This alternative would allow controlled development within the study area and, by itself, would not significantly alter the existing social or environmental characteristics. Therefore, this alternative would have a long-term positive impact on the social environment since the potential for ever-increasing flood losses would be reduced.

3.4 Structural Flood Mitigative Schemes

3.4.1 Berms/Raising of Roadways

i) Engineering

In other areas, one of the most cost-effective schemes for flood control has been construction of flood control berms or dykes. These berms can take the form of either an earth structure whose alignment is dictated by topography and the area to be floodproofed or the raising of roadways whose secondary function would be that of a flood control structure.

When using berms to provide flood protection, special consideration must be given to its impact on the local drainage system. The final design must include provision for accommodating the local runoff from the catchment area behind the structure.

As noted on Figures 2.1 to 2.5, a significant difference exists within some of the Damage Centres between the area inundated for mean peak flows and the upper 95% confidence limit flows. When considering the use of berms/raising of roadways, the feasibility of providing flood protection for both mean and the upper 95% confidence level conditions was considered in order to evaluate the sensitivity of the protection type and cost with flood level.

When examining the use of earth berms/raising of roadways for flood protection, numerous alignments and degrees of protection warrant investigation in order to determine the most cost effective scheme. The following discussion identifies the alternative schemes assessed at each of the Damage Centres:

i) Damage Centre No. 1 : Steady Brook

For protection to the 1:100 year mean level, the three most feasible alignments for Steady Brook are given in Figures 3.2, 3.3 and 3.4. Details of each scheme are summarized in Table 3.2.

The construction of earth dykes and/or raising of roadways could provide flood proofing protection for the majority of the dwellings presently being subjected to a high flood hazard. The main area where the use of earth berms would be restricted, however, is along the northwestern and western limits of Steady Brook. Here the land is flat requiring a berm having a height in excess of 2.0 m in order to provide 1:100 year flood protection. Associated with this berm height are a number of negative impacts and constraints including; loss of land to accommodate structures (maximum 18 m width estimated), obstruction of the view of the drainage systems (Humber River and Steady Brook) and encroachment onto existing dwellings. The above restraints would limit, and in some cases prevent, the use of earth berms.

To provide flood protection to the 1:100 year 95% confidence level (provides additional protection against ice jam occurrences), the height of the berms would have to be raised an additional 0.8 m. This would result in a berm exceeding a three metre height in some locations. A berm of this height would require a significant width of easement which would encroach onto existing developed area. For this reason, this type of floodproofing cannot be provided in low-lying areas within the northwest corner of the Community of Steady Brook.

The two most feasible alternatives for providing flood protection to the 1:100 year upper 95% confidence level are presented as Schemes D and E on Figures 3.5 and 3.6 respectively. Details of these schemes and others considered are summarized in Table 3.2.

ii) Damage Centres No. 2, 3 and 4

At the smaller communities of Russell, Harrison and Governors Point, flood protection in the form of earth berms and raising of roadways could similarly be provided. A total of seven structures could be protected from the 1:100 year mean water surface elevation and fourteen from the 1:100 year 95% confidence levels, out of a total of 38 structures affected. However, the majority of those structures remaining unprotected (about 80%) are comprised of sheds and cabins with little economic value. The alignment of the proposed berms are shown on Figure 3.7 for Russell, Figure 3.8 for Harrison, and 3.9 for Governors Point. Table 3.2 provides a summary of the characteristics of each scheme.

ii) Benefit Cost Analysis

It is assumed that the main benefit associated with the construction of earth berms/raising of roadways is the complete protection of structures located within the existing 1:100 year floodplain (i.e. complete protection from future flood damages). For the purposes of this analysis, it has been assumed that any structure which has been protected from overland flow is also not affected by the groundwater regime.

Construction cost estimates have been established for each of the above flood mitigative schemes and are summarized in Table 3.3 (to be read in conjunction with Table 3.2). These estimates are based upon an analysis of alternative preliminary engineering concepts. In our opinion these estimates are realistic for budgeting purposes and should be reasonable "orders of magnitude". It should be noted that the estimated costs include preliminary allowances for engineering design, construction supervision and land acquisition for the required easements. A detailed breakdown of the costs for the various schemes is given in Appendix C.

It is evident from the summary of the benefit-cost analysis (i.e. Benefit Cost Ratios), as summarized in Table 3.3, that the most attractive schemes for the Community of Steady Brook were those associated with providing 1:100 year mean level protection. The corresponding benefit-cost ratios ranged from 0.20 to 0.29. However, the low ratios calculated for even these schemes suggest that they are not economically viable.

For Damage Centres 2, 3 and 4 the same results were found. The benefit cost ratios were, however, higher for Centres 2 (Russell) and 4 (Governors Point), being 0.42 and 0.31 respectively.

It should be noted that although a scheme may be found to be economically feasible, other factors such as its environmental and social impacts must also be considered prior to the final selection. For example, flooding of basements due to groundwater has been identified as a concern of residents in Steady Brook, and this factor is not specifically considered in the surface flooding analyses which are discussed above.

iii) Environmental Analysis

The main direct impact of dyke construction is related to the removal of vegetation within residential areas. This is not considered to be significant as mitigative measures could be taken.

Various dyke alternatives involve dykes or berms with elevation of over 3 m. This would seriously impair visual sightlines to the river at some locations. Other environmental impacts due to dykes are related to aesthetic changes along the alignment. An attempt is made to consider these in the comments which are summarized in Table 3.2.

3.4.2 Channel Improvements

i) Engineering

The conveyance capacity of a watercourse can sometimes be improved by channel improvements. At each of the four flood damage centres, the discharge capacity of the Humber River during peak runoff periods is, at present, virtually unaffected by any significant obstructions, constrictions, irregularities of the channel bottom, etc. As a result of the mild slope of the Humber River (i.e. 0.002 m/m), and the absence of any channel irregularities within the study reaches, widening of the channel would not have any significant impact on the flood levels.

It should be noted that along the downstream reach of Steady Brook (below the CN trestle), the flooding levels are affected by the tailwater from the Humber River. The Community of Steady Brook (Damage Centre No. 1) is, therefore, subjected to a flood hazard from both the Humber River and Steady Brook systems. However, the timing of peak flows and water levels on the Humber River and Steady Brook generally do not coincide. Therefore, additional HEC-2 computations were undertaken along Steady Brook assuming negligible tailwater effects from the Humber River. The results of this investigation, as summarized in Table 3.4, indicate that the flooding resulting from flows along the Steady Brook system were confined to only the low lying areas where there is little existing development.

In summary, it was found that making channel improvements to either drainage system would have a negligible impact on the flood hazards associated with the four Damage Centres.

ii) Benefit Cost Analysis

As indicated in Section i), this approach was not found to be feasible. A benefit cost analysis was, therefore, not undertaken.

iii) Environmental Analysis

Any channel widening and deepening of the existing river would cause major impacts to the aquatic environment, such as disruption of fish habitat, decreasing water quality, etc.

3.4.3 Ice Control Measures

i) Engineering

A review of historical flood conditions (8, 11) has indicated that ice jams have not been a problem along the Humber River. An assessment of measures to control/minimize ice jam occurrences along the Humber River was, therefore, not considered warranted.

On the other hand, Steady Brook has been known to be susceptible to ice jam occurrences. The primary area of concern is in the vicinity of its confluence with the Humber River up to the Trans Canada Highway.

Results of the HEC-2 simulations indicate that the average velocity and Froude number along the downstream reach were in excess of 1.4 m/s and 0.11 respectively. This confirms the moderate to high potential for ice jam formation as previously observed.

Results of the hydrotechnical study completed on Steady brook indicate that the main channel upstream of Steady brook is relatively straight and steep with channel slopes averaging in the order of 0.021 m/m. A suitable floodplain site for the storage of ice was not found in the steep valley upstream of the Community of Steady Brook.

Between the confluence with the Humber River and the C.N.R. trestle, the channel gradient flattens, with the floodplain exceeding 400 m in width. This reach, from an hydraulic viewpoint, is more promising for use as an ice storage area. However, the low elevation of the surrounding lands, which are presently developed, limits the allowable increase in head on which to create the required storage. Also, this area is already prone to open water flooding for a 1:20 year event, and therefore, it was concluded that the presence of an ice control structure, which would in itself increase flood levels, was not feasible.

Based on historic information, an ice cover generally exists at the confluence of Steady Brook with the Humber River when the peak spring outflow occurs from Steady Brook. The presence of this ice cover acts as an obstruction for any ice which is conveyed downstream by Steady Brook. To remove this ice barrier, the adoption of a blasting program could be considered. The purpose of blasting is to fracture the existing cover in an effort to promote early release of small ice floes prior to the high spring runoff. Blasting is labour intensive and requires a highly experienced and knowledgeable team to be carried out safely and effectively. In addition, accurately forecasting the timing of freshet is a severe problem, especially for flashy streams like Steady Brook. A regular blasting program was, therefore, not considered to be a feasible alternative.

To help minimize the potential for ice jam occurrences along the downstream reach of Steady Brook, removal of the existing obstructions was also considered. The locations where excavation/dredging are required are shown on Figure 3.10. The advantages associated with this technique include:

- promote stable cover formation (velocities less than 0.6 m/s; Froude numbers below 0.08)
- lowers water level with ice jams
- improves channel conveyance during open water conditions
- reduces potential for jam initiation and flooding
- increases hydraulic capacity

- increases channel ice storage (9000 m^3 of additional storage area created

Although removal of the obstructions would have a definite impact on reducing the potential for ice jam occurrences especially during the more frequent runoff events, the economic benefits associated with the scheme cannot be accurately assessed due to the unpredictability of ice jam formation, location, movement and impact on flood levels and damages.

ii) Benefit Cost Analysis

As indicated in Section i), the benefits associated with removal of the obstructions can not be quantitatively identified. However, a crude estimation as to the maximum benefit which could be potentially attributed to this scheme can be evaluated. Based on previous experience in relating the effects of ice jams on flood damages, and in considering the maximum number of structures potentially affected, the benefit-cost ratio for this scheme would definitely be less than 0.7. (This assumes as an ultimate benefit that no future ice jams will occur as a result of the scheme, which is in all likelihood not the case. Furthermore, it conservatively assumes that ice jams would cause damages on an annual basis, would be of equal magnitude each year and would have the same characteristics each year). A cost of $103,000 (present value) was estimated for the proposed dredging and excavation. A detailed cost summary is included in Appendix C.

In our opinion, this work should be undertaken to improve flow conveyance and minimize the potential for ice jams. While the economic benefits can only be approximated, it must be recognized that there would be some corresponding reduction in the potential for personal injury, and loss of life, etc. However, care should be exercised in the ultimate evaluation of the effectiveness of this scheme in terms of cost and effectiveness as a remedial measure.

iii) Environmental Analysis

Impacts on the aquatic environment would be significant due to disruption of the benthic community and the general structure of the aquatic ecosystem. This could have a long term effect on fish populations, water quality, and plant growth. Further study on the biological attributes of Steady Brook should be considered before the feasibility of this alternative from an environmental point of view can be completely analysed.

3.4.4 Floodproofing/Relocation

a) Raising Existing Homes

i) Engineering

The raising of homes (i.e. first floor elevation) to an elevation above the adopted design flood level has been a successful method of reducing potential flood damages within a hazard area. Increases in height in excess of three metres have been successful. However, the ease in completing such an undertaking is dependent on the accessibility for jacking, weight, size and type of building, structural stability and site conditions. It should be noted that in addition to simply raising the structure, the impacts to aesthetics and the landscaping requirements must also be considered.

Although raising of the structures would prevent flooding of the first floor, basement flooding would still occur. However, local residents have suggested that basement flooding (i.e. due to groundwater) would not be as frequent if the basement floor elevation was higher. We agree that this is likely to be the case.

A summary of the residential structures affected, their depth of flooding for both the 1:100 year mean and 95% confidence levels is given in Table 3.5. The location of the affected structures are shown on Figures 3.11 to 3.15 for the Community of Steady Brook, Russell, Harrison and Governors Point respectively.

In summary, it was found that in the Community of Steady Brook four structures would require raising to provide protection to the 1:100 year mean level. The number increases to twelve for the 1:100 year upper 95% confidence level. At Harrison, Russell and Governors Point, the total number of structures varied from seven for the 1:100 year mean level protection to fourteen for the 95% confidence level. The average increase in wall height, taking into consideration the affected homes at all four study areas was 0.54 m and 0.87 m for the mean and 95% confidence levels respectively. As the required increases were well within the acceptable range for structural modifications to a building, raising of the structures was considered to be a feasible flood mitigative scheme.

For those structures where raising was not practical, an evaluation as to the effectiveness of sealing low water entry points may be a viable alternative. This was subsequently evaluated in conjunction with the raising of structures in Phase II of these investigations.

ii) Benefit Cost

The raising of the first floor elevation of existing homes above the 1:100 year flood level would have a significant impact on reducing flood losses. While first floor flood losses would be reduced, it was assumed that basement flooding may still occur due to overland flow. It should be noted that this flood mitigative scheme would have minimal impact on the indirect damages such as; road closures, inconvenience and losses associated with power failure, increased traffic accidents, etc.

In order to provide 1:100 year mean level protection within the study area, ten structures would require raising, the average increase in the first floor elevation being 0.4 m. For 1:100 year upper 95% confidence level protection, the number of structures affected increased to 26, with an average increase of 0.9 m. However, The raising of structures to protect to the upper 95% 1:100 year level was found to be undesirable from an aesthetic point of view. (Some structures would require raising by more than 2.0 m.)

The cost associated with the raising of a structure is dependent on a number of factors including; magnitude of the height increase, size of the structure, aesthetics, etc. For the cost estimate it has been assumed that each dwelling would be raised independently. That is to say, no saving has been assumed if one contractor was given the contracts to raise more than one structure at a given time. The total cost for providing 1:100 year mean level flood proofing protection at all four damage centres was estimated to be $61,000. (The costs could total $156,000 if the 1:100 year upper 95% confidence level was to be adopted for flood protection.) A summary of the estimated costs for each damage centre is given in Table 3.6. A detailed cost breakdown is included in Appendix C.

The benefit cost analysis indicated that this remedial measure was economically attractive (would effectively floodproof to the 1:100 year level). At all damage centres the benefit cost ratios either exceeded or approached one (see Table 3.7).

iii) Environmental Analysis

This scheme would have no impacts on the natural environment since no disruption of the existing conditions would occur. Likewise, the impacts to the social environment are negligible except for minor inconvenience during construction.

b) Relocation

i) Engineering

Selected homes and flood prone structures could be moved to non-hazard areas. However, relocation has numerous drawbacks which makes it less attractive than other schemes. Structures of brick, stone, masonry or concrete are difficult and costly to move. In addition to moving the structure, other costs include the purchasing and preparation of the new property, lot grading, utility servicing, moving and landscaping. In addition, relocation schemes elsewhere have resulted in dissatisfaction of the owners who would be required to relocate. Overall, this was not considered to be an attractive alternative.

ii) Benefit Cost Analysis

As this scheme was not considered to be feasible, a detailed benefit-cost analysis was not undertaken. However, making rough estimates for moving, land costs, utility connections, landscaping, etc., potential costs were estimated to be in excess of 7 to 10 times the possible flood benefits.

iii) Environmental Analysis

This alternative would result in a major impact to the existing social conditions within the study area. The dismantlement of a community not only represents an upsetting inconvenience, but it also represents costs to the local residents that cannot be quantified. This will include distance and inconvenience to travel to workplace, relatives, shopping, etc. Due to the magnitude of these unmitigatable impacts, this scheme is not considered feasible.

3.4.5 Improvement to Residential Tile Drainage Systems

i) Engineering

It was evident from the flood damage questionnaire that a number of the residents are under the impression that basement flooding is primarily a result of surcharging of the groundwater table in conjunction with high flows on the Humber River. Preliminary soils investigation indicated that the soil permeability within the Steady Brook area is greater than the regional average. In view of the high permeability of the soils in the study area and the duration of the high flows along the Humber River system, the possibility of a high groundwater table, especially in the immediate vicinity of the river, could not be ruled out. (For the June 1984 event, high flows were experienced for more than a week.)

Basement flooding resulting from a high groundwater table would suggest that the drainage system around the basement wall is not functioning as efficiently as originally designed. This could be the result of insufficient quantity of filter material (i.e. granular) being placed adjacent to the walls, the basement wall not being adequately waterproofed and/or the sump pump capacity being exceeded by the groundwater inflow. To resolve the problem each site would require an independent assessment.

The efficiency of the existing drainage tile system would have to be assessed to resolve the problem of basement flooding. In order to complete a proper evaluation, the entire system around each house would have to be exposed. In view of the costs associated with such an evaluation, a more attractive approach would be to install a completely new drainage system. This would ensure that any basement flooding problems which may be due to inadequate tile drain systems are resolved.

To minimize the groundwater inflow to the tile drainage system, the placement of an impermeable membrane at the outer limit of the granular material could be considered. This would help to minimize that area around the dwelling where the water level must be drawn down. Figure 3.16 shows a schematic of the proposed scheme.

ii) Benefit Cost

Improving the efficiency of a drainage system would not provide floodproofing protection when a residential structure is being subjected to an overland flow condition. Determination of groundwater movement and flooding conditions was beyond the scope of this investigation.

iii) Environmental Analysis

The proposed improvement would have no significant positive or negative impact on the existing environmenal conditions.

3.4.6 Deer Lake Detention Structures

i) Engineering

The SSARR simulations indicated that the natural storage in Deer Lake has an impact on the outflow along Steady Brook. However, in order to take full advantage of flood control benefits, the installation of a dam at its outlet would be required. The purpose of this dam would be to utilize the storage available at the higher elevations while limiting the peak outflow to an acceptable level.

The most appropriate location for the structure would be at a narrows located approximately 1300 m downstream of Governors Point. Here the river banks are steep, allowing a potential rise in Deer Lake level in excess of 7 m above the normal water level before being overtopped. The width of the river at this location is in the order of 90 m.

A flood control assessment was undertaken using the SSARR model for the June 1984 runoff event. This event has approximately a 1:10 year return period. For the computations, it was assumed that the peak outflow from Deer Lake could be restricted to 708 m^3/s by a flood control structure. This flow represents the condition at which significant flood damages commence at downstream locations.

By means of the SSARR simulations, it was found that in order to provide 1:10 year level of protection along the Humber River, the Deer Lake water level would increase approximately 1.2 m. In terms of historical lake levels, this would be equivalent to roughly a 1:250 year event. In view of the development which has occurred around Deer Lake and its close proximity to the shoreline, such an increase in water level would, in our opinion, not be acceptable. It should also be noted that the presence of a flood control structure would have a negative impact on the logging operation as its presence would hinder the movement of logs downstream.

ii) Benefit Cost Analysis

In our opinion, any downstream flood benefits which would result from the construction of a dam at the outlet of Deer Lake would likely be offset by the increased flood hazards along the upstream area (i.e. shoreline of Deer Lake).

The cost for the construction of a flood control structure at Deer Lake is estimated to be in excess of $1,500,000. In addition to this cost, flood easements around Deer Lake would also be required. In view of the limited benefits associated with this scheme and the high capital expenditure, it is evident that such a scheme is not economically feasible.

iii) Environmental Analysis

This proposed scheme would result in an increase in water levels in excess of 1-2 metres. This would cause the inundation of areas that are now dry, thus changing the features of the littoral zone of Deer Lake. This flooding would result in the loss of some terrestrial habitat, decrease water quality due to decomposing organic matter (flooded trees, shrubs, etc.) and would certainly impact on private property. As well, Deer Lake maintains a healthy cold water fisheries which is very sensitive to change in the ambient conditions of the lake.

Furthermore, the lake is part of the regional logging activities in that large log booms are floated down the lake and then down the Humber River. A structure at the narrows downstream of Governors Point would disrupt the normal logging operation and a bypass channel would have to be incorporated into the design of the structure at additional cost.

TABLE 3.1

Summary of Affected Structures*

Damage Centre No.	Location	Design Condition 1:100 Year	 1:100 Year 95% Upper Confidence
1	Community of Steady Brook	20	36
2	Russell	4	18
3	Harrison	7	15
4	Governors Point	2	5

* Includes all residential/commercial structures plus all ancillary structures (i.e. sheds, garages, etc.)

TABLE 3.2
Summary of Berms/Raising of Roadway Flood Mitigative Schemes

Damage* Centre No.	Scheme	Type	Details	No. of Residential Structures Flood Proofed	Advantages	Disadvantages
1	A	Earth Berms	Reach 1 - 300 m length earth berm - Max. depth = 1.5 m - Rip rap erosion protection required - Rip rap erosion protection required	5	- Earth construction - All roadways floodproofed - Provides complete flood proofing protection up to 1:100 year event for Steady Brook - Minimal impact on landuse & transportation network - Provides protection for low-lying area to west - minimize impact on natural environment	- Berm obstructs view of Humber River and accessibility - Due to land constraints berm may encroach Steady Brook - Possible depreciation in land value - Disruption of aesthetic value of area
			Reach 2 - 460 m length earth berm - Maximum depth 2.4 m - Rip rap erosion protection required along entire length - Maximum depth = 2.4 m	6		
			Reach 3 - 80 m length Max. depth = 1.5 m - Property acquisition required for all three reaches	3		
			TOTAL	14		
1	B	Combination earth berms & raising of roadways	Reach 1 - 300 m length earth berm - Max. depth = 1.5 m - Rip rap erosion protection required - Property acquisition required	5	- Provides complete flood proofing protection up to 1:100 year event - Although floodproofed Reach 3 would be isolated from the mainland in the event of a design storm - Minimal impact on natural environment	- At 2 locations berm encroaches onto both Humber River & Steady Brook - Berm encroaches onto existing development - Raising of roadways would have a temporary negative social impact - May change aesthetic quality of study area
			Reach 2 - 230 m length earth berm - Max. depth = 2.3 m - 2 driveways require raising - 70 m of berm which parallels Humber River requires erosion protection	2		
			Reach 3 - 110 m of raised roadway to design elevation - 150 m of earth berm max. depth of earth berm = 2.4 m	2		
			Reach 4 - 80 m length of raised roadway - Max. depth is 1.0 m - 3 driveways require raising	3		
			TOTAL	12		

TABLE 3.2 (cont'd)

Damage* Centre No.	Scheme	Type	Details	No. of Residential Structures Flood Proofed	Advantages	Disadvantages
1	C		Reach 1 - 300 m length of earth berm - Max. depth = 1.5 m - Berm parallels shoreline ∴ erosion protection required - Property acquisition required	5	- Provides complete flood proofing protection of the 1:100 year event - All roadways would be floodproofed in addition to residential dwellings - Minimal impact on natural environment	- Berm encroaches onto Humber River & Steady Bk. systems - Due to height of berm both view of Humber R. & Steady Brook would be obstructed - Accessibility to drainage systems limited
			Reach 2 - 80 m length earth berm parallels Humber River. Erosion protection required - 400 m of earth berm - Max. depth of 2.4 m - Property acquisition required	5		
			Reach 3 - 130 m length of raised roadway - Max. depth is 1.0 m - 3 private drives require raising	3		
			TOTAL	13		
1	D	Raising of roadway	Reach 1 - 430 m length of raised roadway - Max. depth = 2.0 m - 16 private drives require raising	11	- Provides 1:100 year upper 95% conf. level protection - Falls Ave. & Woodland Place would be floodproofed - Minimal impact to natural environment	- Provides no protection to western area of Community which is subjected to more frequent flooding - Low lying area to west not protected - Development along Humber River not protected - Temporary impact to social environment
1	E	Combination earth berms and raising of roadway	Reach 1 - 230 m of raised roadway - Max. depth = 0.6 m - 10 private drives require raising Reach 2 - 300 m of earth berm - Max. depth = 2.5 m - Property acquisition required - 150 m of raised roadway - Max. depth 2.0 m - 3 private drives require raising	13	- Provides 1:100 year upper 95% conf. level protection - Falls Ave. & Woodland Place would be floodproofed - Minimal impact to natural environment	- Provides no protection to western area of Community which is subjected to more frequent flooding - Raising of roadways would have negative social impact - Low lying area of Community to west not protected - Development along Humber River not protected - Temporary impact to social environment

TABLE 3.2 (cont'd)

Damage* Centre No.	Reach	Type	Details	No. of Residential Structures Flood Proofed	Advantages	Disadvantages
2	1	Earth Berm	- 130 m length earth berm - Berm parallels river, therefore erosion protection required - Property acquisition required - Structure required to accommodate outflow from drainage behind berm - Maximum height of berm is 1.7 m	3	- Provides flood proofing protection to 1:100 year upper 95% confidence level - Protects 4 structures (Structure ID #1,2,3)	- Accessibility to Humber River limited - Obstruct view of river - Minor impacts to social environment
	2	Earth Berm	- 120 m length earth berm - Maximum height 1.0 m - Property acquisition required - Portion of berm coincident with river bank. Rip rap protection required - Drainage culverts required	1	- Provides complete flood proofing protection to 1:100 year upper 95% confidence level - Protects one residential structure (ID #14)	- Alignment affected by development constraints - Obstructs view of river with minor impacts to social environment
	3	Earth Berm	- 120 m length earth berm - Maximum height 0.8 m - Portion of berm coincident with river bank. Erosion protection required - Drainage culverts required	1	- Provides flood proofing protection to the 1:100 yr. upper 95% confidence level - Protects one residential structure (ID #13)	- Alignment affected by development constraints - Minor impact to private property
			TOTAL	5		
3	1	Earth Berm	- 170 m length of earth berm - Maximum height 2.0 m - That portion of berm paralleling Humber R. requires rip rap protection - Property acquisition required - Two drainage culverts required	2	- Provides 1:100 year upper 95% confidence level protection - Protects two residential structures (ID #2 & 3)	- Berm obstructs view of Humber River and accessibility - Minor impacts to private property
	2	Combination earth berm & raising of roadway	- 190 m length of earth berm - Maximum height 2.7 m - 120 m of raised roadway. Maximum height 2.7 m - Modifications required to two private drives - Property acquisition required	2	- Provides 1:100 yr. upper 95% confidence level protection - Protects two residential structures (ID #4 & 5)	- Berm obstructs view of Humber River and accessibility - Temporary disruption of traffic flows
			TOTAL	4		

TABLE 3.2 (cont'd)

Damage* Centre No.	Reach	Type	Details	No. of Residential Structures Flood Proofed	Advantages	Disadvantages
3	2	Combination earth berm & raising of roadway - 1:100 yr. mean level protection	- 180 m length of earth berm - Max. height of berm 2.0 m - 80 m length of raised roadway - Max. height 2.0 m - Rip rap protection required along that portion which parallels river - Modifications required to two private drives - Property acquisition required - Two drainage culverts required	2	- Provides 1:100 year mean level protection - Protects two residential structures (ID #4 & 5)	- Earth berm obstructs view of river - Temporary disruption of traffic flows
			TOTAL	2		
4	1	Earth berm	- 310 m length, maximum height 2.0 m to provide 1:100 yr. upper 95% confidence level of protection - 140 m length, max. height 1.0 m to provide 1:100 yr. mean level protection - Two drainage culverts required	4	- Provides protection up to 1:100 yr. upper 95% confidence level - Protects four residential structures (ID #1, 2, 3 & 4)	- Berm obstructs view of Humber River and accessibility if 1:100 year 95% confidence level is selected - Minimal impacts to social environment
			TOTAL	4		

* Refer to the following figures for location of damage centres:

Damage Centre No. 1 - Figure 2.1
Damage Centre No. 2 - Figures 2.2 & 2.3
Damage Centre No. 3 - Figure 2.4
Damage Centre No. 4 - Figure 2.5

TABLE 3.3

Summary of Benefit Cost Analysis

Berms/Raising of Roadways

Damage Centre No.	Location	Existing Condition Total Damages* ($)		Flood** Mitigative Scheme	Total Damages* ($) Under Proposed Scheme		Total Benefit* ($)		Construction Cost ($)	Benefit Cost Ratio	Net Present Value ($) Proposed Scheme
		Mean	+95% C.L.		Mean	+95% C.L.	Mean	+95% C.L.			
1	Steady Brook	89,300	245,500	A	0	-	89,300	-	380,000	0.24	-290,700
		89,300	245,500	B	23,300	-	66,000	-	242,000	0.29	-176,000
		89,300	245,500	C	22,500	-	66,800	-	335,300	0.20	-268,500
		89,300	245,500	D	-	222,900	-	22,600	257,000	0.09	-234,400
		89,300	245,500	E	-	222,100	-	23,400	322,000	0.07	-298,600
2	Russell	19,200			5,700	-	13,500	-	Not recommended	-	-
			58,400			24,100	-	34,300	81,000	0.42	-46,700
3	Harrison	51,000			38,300	-	12,700	-	86,300	0.15	-73,600
			95,600			60,700	-	34,900	203,700	0.17	-148,800
4	Governors Point	8,300			0	-	8,300	-	Not recommended	-	-
			23,000		-	0	-	23,000	73,600	0.31	-50,600

* Present value, based on an effective interest rate of 10% and 50 year design life

** Flood Mitigative Scheme A : Earth berms
B : Combination of earth berms and raising of roadways
C : " " " " " "
D : Raising of roadways
E : Combination of earth berms and raising of roadways

For a summary description of the flood mitigative schemes, see Table 3.2

TABLE 3.4

Summary of Computed Water Levels
Community of Steady Brook

Design Storm	Humber River	Steady Brook
1:5	5.02	3.67
1:10	5.39	3.70
1:20	5.74	3.96
1:50	6.17	4.03
1:100	6.50	4.11

TABLE 3.5

Summary of Structures to be Raised

Damage Centre No.	Location	First Floor Elevation (m)	Required Raising of Structure (m) 1:100 Yr. (Mean)	Required Raising of Structure (m) 1:100 Yr. (+95% C.L.)
1	Steady Brook			
	#1 Brook Road	7.02	Nil	+0.38
	#2 " "	6.82	Nil	+0.58
	#2 Falls Ave.	7.9	Nil	Nil
	#3 " "	7.5	Nil	Nil
	#4 " "	7.5	Nil	Nil
	#5 " "	8.3	Nil	Nil
	#7 " "	7.5	Nil	Nil
	#9 " "	7.7	Nil	Nil
	#11 " "	7.5	Nil	Nil
	#13 " "	7.83	Nil	Nil
	#17 " "	6.44	+0.1	+1.00
	#17B " "	5.82	+0.7	+1.60
	#15 " "	7.00	Nil	+0.40
	#1 Forest Drive	6.40	+0.1	+1.00
	#2 " "	6.63	Nil	+0.8
	#3 " "	7.80	Nil	Nil
	#4 " "	5.83	+0.7	+1.57
	#5 " "	7.86	Nil	Nil
	#6 " "	7.18	Nil	+0.22
	#7 " "	7.39	Nil	Nil
	#8 " "	7.9	Nil	Nil
	#9 " "	6.40	Nil	+1.0
	#10 " "	8.0	Nil	Nil
	#11 " "	7.11	Nil	+0.29
	#12 " "	8.1	Nil	Nil
	#13 " "	6.80	Nil	+0.60
	#14 " "	8.1	Nil	Nil
	#15 " "	7.74	Nil	Nil
	#15B " "	6.00	+0.5	+1.4
	#16 " "	8.2	Nil	Nil
	#17 " "	8.00	Nil	Nil

TABLE 3.5 (cont'd)

Summary of Structures to be Raised

Damage Centre No.	Location	First Floor Elevation (m)	Required Raising of Structure (m)	
			1:100 Yr. (Mean)	1:100 Yr. (+95% C.L.)
2	Russell			
	#1	7.5	+0.3	+1.2
	#2	7.8	Nil	Nil
	#3	8.0	Nil	Nil
	#4	7.5	Nil	+0.2
	#5	7.9	Nil	Nil
	#6	7.9	Nil	Nil
	#11	6.3	+0.5	1.4
	#12	6.5	+0.5	1.2
	#13	7.9	Nil	Nil
	#14	7.9	Nil	Nil
	#15	7.5	Nil	+0.2
3	Harrison			
	#1	7.8	Nil	Nil
	#2	7.2	Nil	+0.5
	#3	7.0	Nil	+0.7
	#4	6.8	+0.1	+0.9
	#5	7.7	Nil	Nil
	#6	6.2	+0.6	+1.5
	#7	5.3	+1.5	+2.4
4	Governors Point			
	#1	8.3	+0.4	+1.3
	#2	8.5	+0.2	+1.1

TABLE 3.6

Construction Cost Summary

Raising of Structures

Damage Centre No.	Location	Design Event	Construction Cost
1	Steady Brook	1:100 Year Mean	$ 27,000
		1:100 Year +95% C.L.	95,500
2	Russell	1:100 Year Mean	17,900
		1:100 Year +95% C.L.	25,000
3	Harrison	1:100 Year Mean	18,500
		1:100 Year +95% C.L.	45,000
4	Governors Point	1:100 Year Mean	9,000
		1:100 Year +95% C.L.	32,400

TABLE 3.7

Summary of Benefit Cost Analysis

Raising of Structures

Damage Centre		Existing Condition Total Damages* ($)		Total Damages* ($) Under Proposed Scheme		Total Benefit*		Construction Cost ($)	Benefit Cost Ratio	Net Present Value of Proposed Scheme ($)
No.	Location	Mean	+95% C.L.	Mean	+95% C.L.	Mean	+95% C.L.			
1	Steady Bk	89,300	-	51,700	-	37,600	-	27,000	1.39	10,600
			245,500		33,600	-	211,900	95,500	2.21	116,400
2	Russell	19,200	-	17,840	-	1,360	-	17,900	0.07	-16,540
			58,400		54,400	-	4,000	25,000	0.16	-21,000
3	Harrison	51,000	-	18,400	-	32,600	-	18,500	1.76	14,100
			95,600	-	50,600	-	67,400	45,000	1.50	22,400
4	Governors	8,300	-	0	-	8,300	-	9,000	0.92	-700
	Point		23,000	-	1,800	-	21,200	32,400	0.65	-11,200

* Present Value, based on an effective interest rate of 10% and 50 year project life

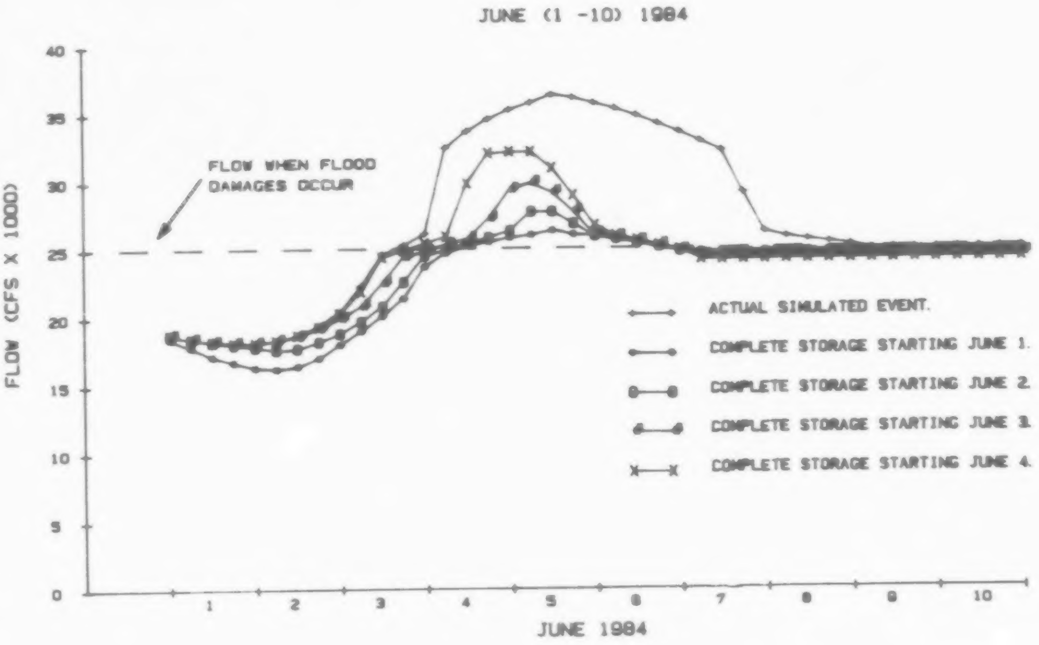
TABLE 3.8

Summary of Appraisal of Alternative Flood Mitigative Schemes

Flood Mitigative Scheme	Engineering Analysis	Benefit/Cost Analysis	Environmental Analysis	Comments
Status Quo	No benefits to existing flood hazards	B/C = 1.0	No Impact	Assumes that compensation would be paid for future flood losses
Flood Forecasting/ Warning System	Could protect basements of flood prone structures, moveable 1st floor items	less than 0.10	Protect loss of life No significant impact	Feasibility scheme low since forecasting judged ineffective due to complexity of system
Property Acquisition	Total of 65 residences would be affected	B/C=0.19 (1:100 mean) B/C=0.25 (1:100 95% upper level)	Major disruption to local community	Feasibility of both schemes considered to be low Further assessment not considered to be feasible
Modifications to Upstream Reservoir Operations	Must be used in conjunction with flood forecasting technique	B/C = 0.12 to 0.21	Significant changes to annual lake levels	Warrants consideration in Phase II
Floodplain Management Policy	Protects future development No benefit as existing development	Not Applicable (Fed./ Prov. regulations now in place)	No impacts, restricts development	Not considered to be the ultimate solution as it provides no immediate flood proofing protection Should be included in overall watershed management scheme
Berms/Raising of Roadways - Damage Centre 1 - Steady Brook				
Scheme A	Provides overland floodproofing protection Proposed structures must accommodate local drainage Land constraints may affect berm alignments	B/C=.24 (1:100 Mean)	No impact to natural environment Disruption of local traffic during construction Obstruct view of river	Feasibility of scheme - low
B		B/C=.29 (1:100 Mean)		" " - low
C		B/C=.20 (1:100 Mean)		" " - low
D		B/C=.09 (1:100 +95% C.L.)		" " - low
E		B/C=.07 (1:100 +95% C.L.)		" " - low
No. 2 - Russell		B/C=.42 (1:100 +95% C.L.)		" " - moderate
No. 3 - Harrison		B/C=.17 (1:100 +95% C.L.)		" " - low
No. 4 - Governors Pt.		B/C=.31 (1:100 +95% C.L.)		" " - moderate
				Feasibility of use of berms/raising of roadways for flood proofing protection considered to be low Inclusion in Phase II analysis not considered to be warranted

TABLE 3.8 (cont'd)

Flood Mitigative Scheme	Engineering Analysis	Benefit/Cost Analysis	Environmental Analysis	Comments
Channel Improvements - Dredging	Minimum improvements to flood levels, some effect on reducing ice jam potential	Maximum potential B/C 0.7 (Estimate only, would not be realized	Significant impacts to aquatic environment	Inclusion in Phase II warranted considering effects of ice quantitave evaluation not possible
Ice Control Measures	Neither a structural or non-structural approach to ice management was found to be feasible Suitable site for an ice control structure not found on the Steady Brook system	Not undertaken	Significant impacts to aquatic environment	Inclusion in Phase II not considered warranted (see also Channel Improvements - Dredging)
Floodproofing/Raising of Structures Damage Centre 1	Provides protection to the 1:100 Yr 95% Conf. level	B/C = 2.21	Temporary disruption to social environment No significant impact to natural environment	In view of high benefit cost ratios, its inclusion in Phase II was considered warranted
2	Basement flooding would still occur under design storm event	B/C = 0.16		
3	Scheme provides no protection to transportation routes	B/C = 1.50		
4	Affected structures would be isolated from mainland	B/C = 0.92		
Relocation	Total of 65 residential structures	B/C=0.19 (1:100 Mean) B/C=0.25 (1:100 95% Conf)	Major disruption to community matrix	Further assessment not considered to be feasible
Improvements to Residential Tile Drainage System	Provides protection against high groundwater table Requires detailed assessment of each tile drainage system located in flood hazard area Protection to overland flow not provided	Not undertaken	No social or environmental impact	As floodproofing protection is not provided for under a surface runoff condition, its inclusion in Phase II was not considered warranted
Deer Lake Retention Structure	Available storage not large enough to provide flood proofing protection for the area downstream under even a 1:10 year event	Detailed analysis not undertaken although costs are considered to be prohibitive	Significant impacts to aquatic and terrestrial environments Loss of private property Disruption of logging operations	Adequate storage not available to provide floodproofing protection Its inclusion in Phase II was not considered warranted



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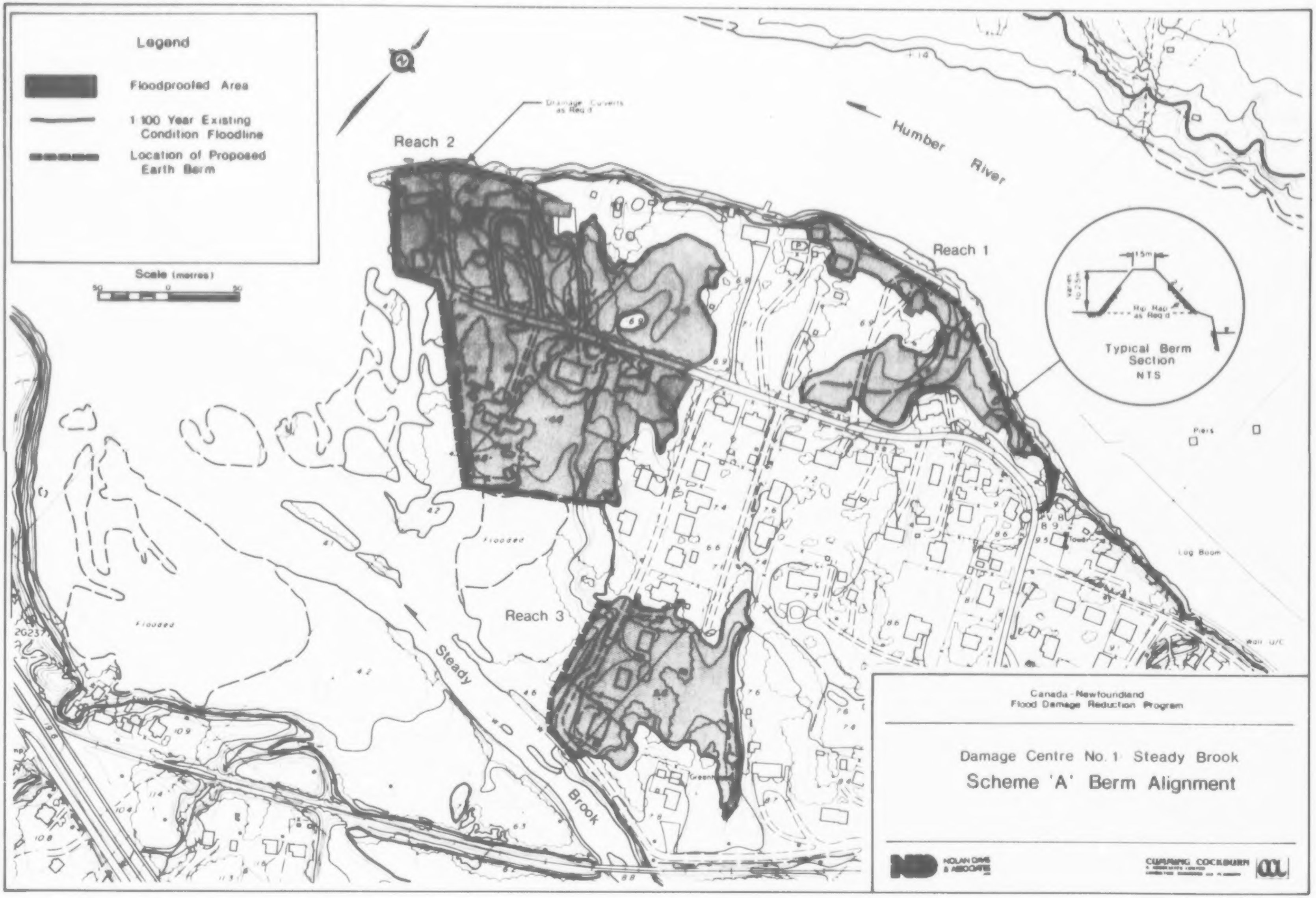
Alternate Operating
Procedures for Grand Lake

Figure 3.1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Floodproofed Area
1:100 Year Existing Condition Floodline
Location of Proposed Earth Berm
Scale (metres)
50
0
50
Drainage Culverts as Req'd
Reach 2
Humber River
Reach 1
15m
Varies to 2.5m
Rip Rap as Req'd
Typical Berm Section
NTS
Piers
Log Boom
Tower
Reach 3
Flooded
Flooded
Steady Brook
Nolan Davis & Associates
Cumming Cockburn

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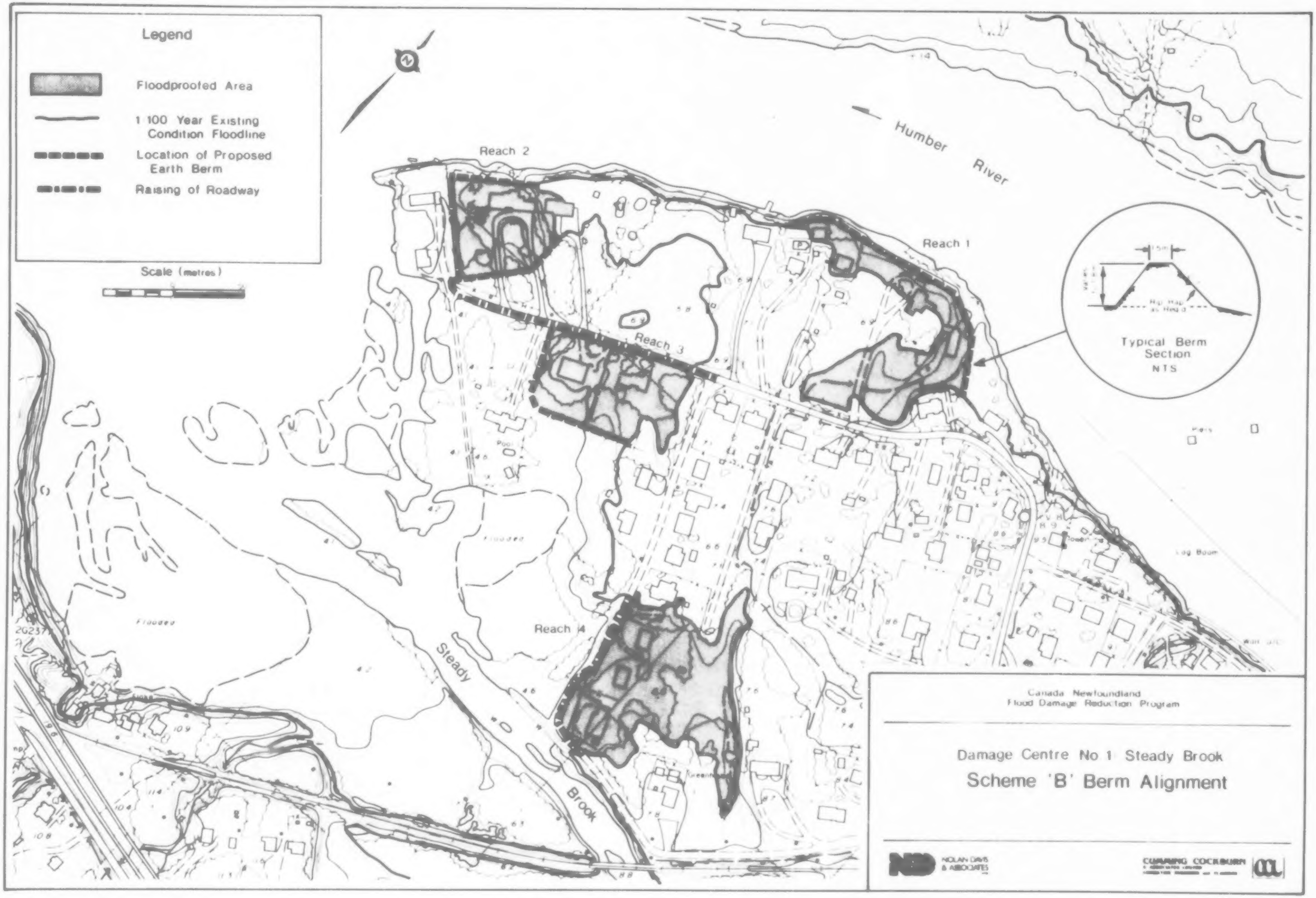
Damage Centre No. 1 Steady Brook
Scheme 'A' Berm Alignment

Figure 3.2


Legend
Floodproofed Area
1:100 Year Existing Condition Floodline
Location of Proposed Earth Berm
Raising of Roadway
Scale (metres)
Humber River
Reach 1
Reach 2
Reach 3
Reach 4
Steady Brook
Typical Berm Section
NTS
Rip Rap as Reqd
Flooded
Pool
Log Boom
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

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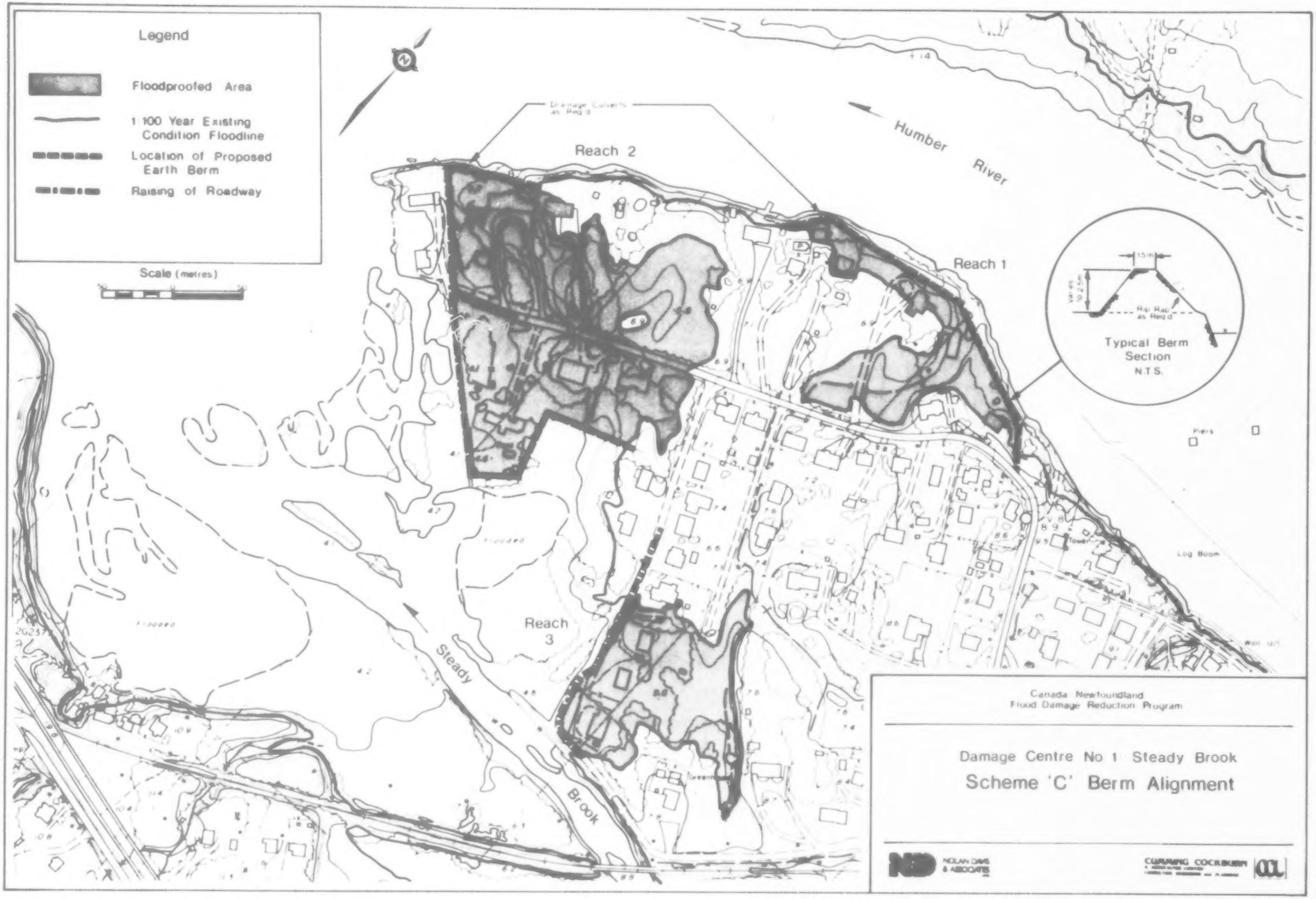
Damage Centre No 1: Steady Brook

Scheme 'B' Berm Alignment

Figure 3.3


Legend
Floodproofed Area
1:100 Year Existing Condition Floodline
Location of Proposed Earth Berm
Raising of Roadway
Scale (metres)
Drainage Culverts as Req'd
Reach 1
Reach 2
Reach 3
Humber River
Steady Brook
Typical Berm Section N.T.S.
1.5m
Varies to 2.5m
Rip Rap as Req'd
Piers
Log Boom
Flooded
Nolan Davis & Associates
Cumming Cockburn

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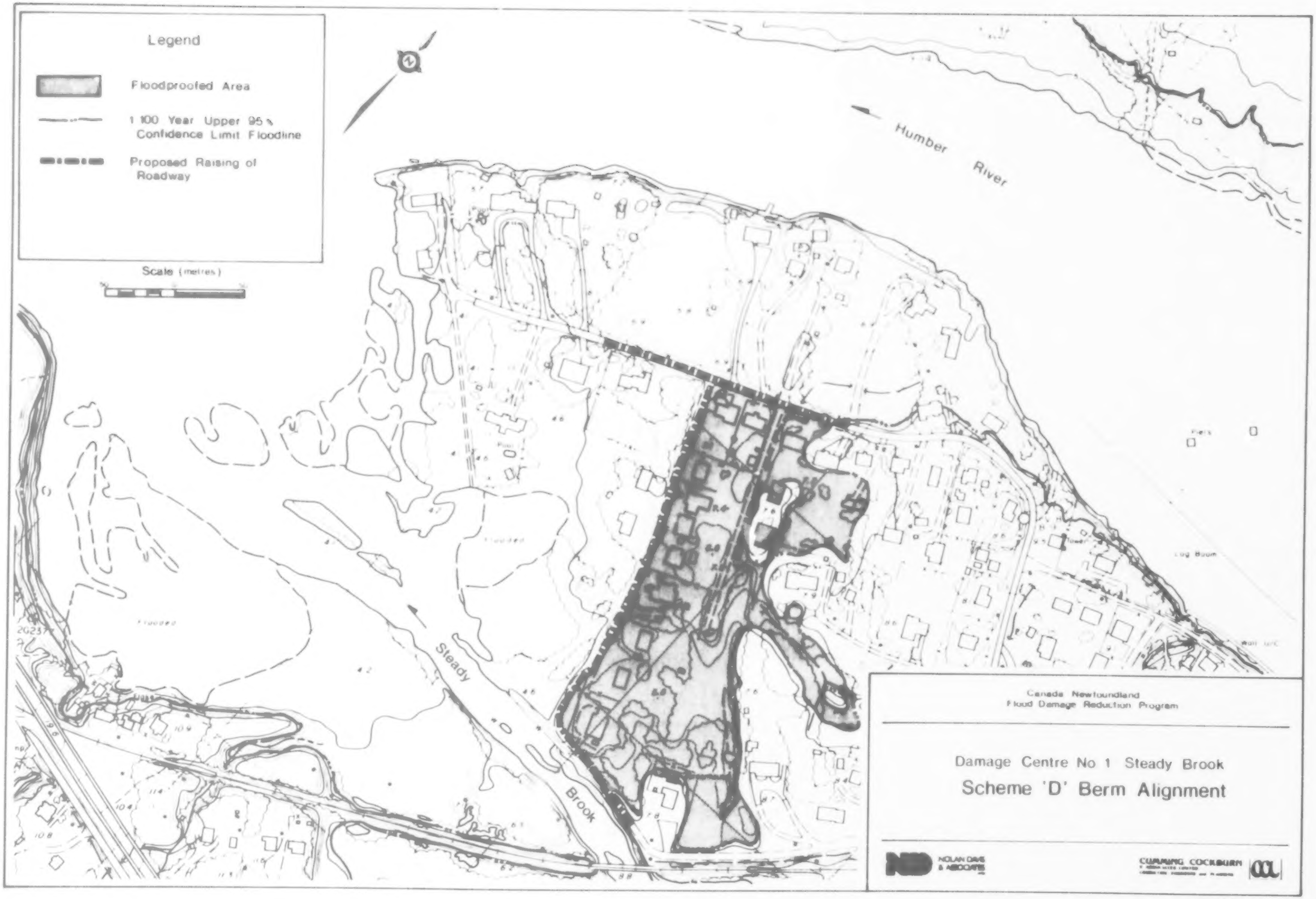
Flood Damage Reduction Program

Damage Centre No 1 Steady Brook
Scheme 'C' Berm Alignment

Figure 3.4


Legend
Floodproofed Area
1:100 Year Upper 95% Confidence Limit Floodline
Proposed Raising of Roadway
Scale (metres)
Humber River
Steady Brook
Flooded
Log Boom
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

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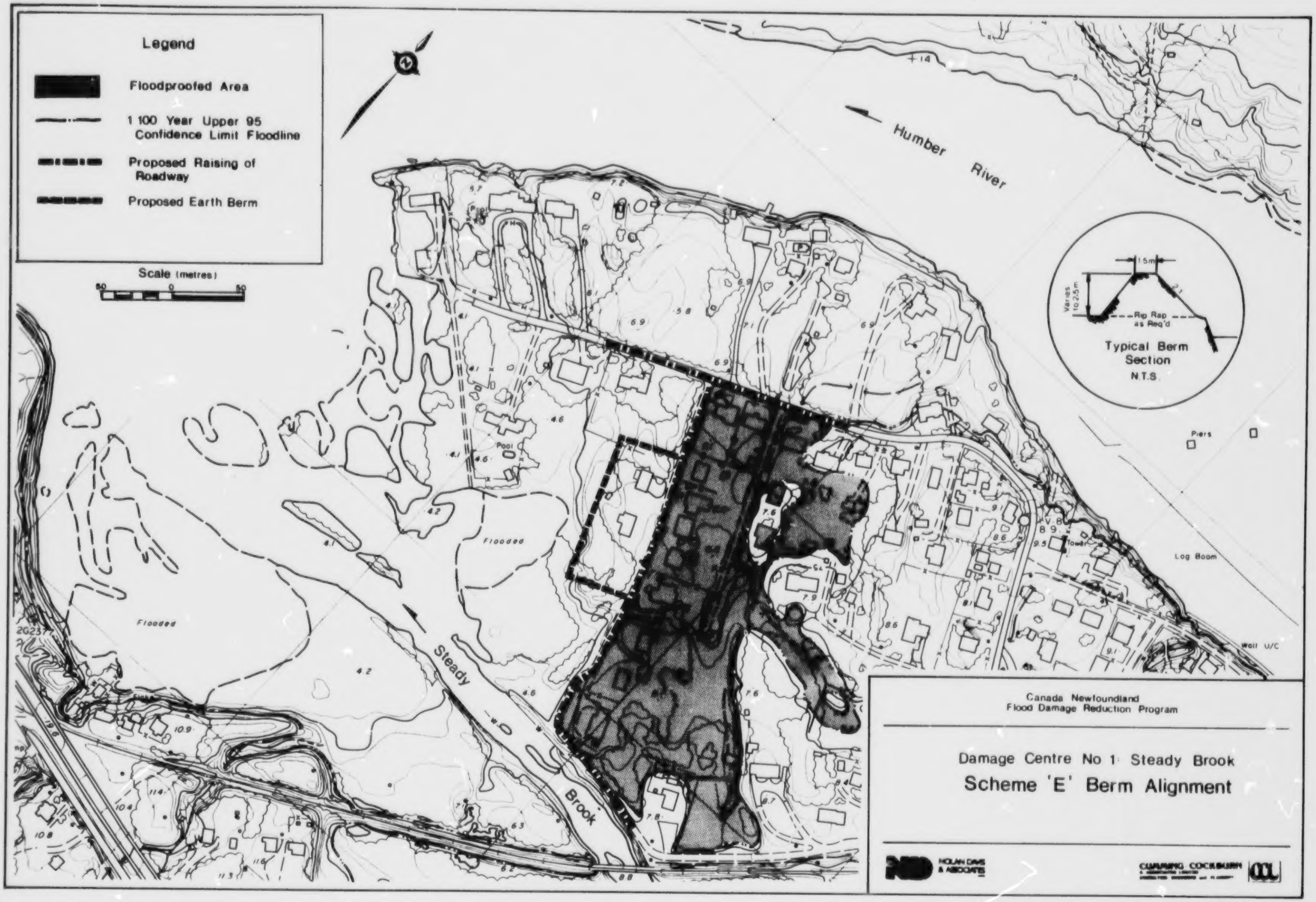
Damage Centre No 1 Steady Brook

Scheme 'D' Berm Alignment

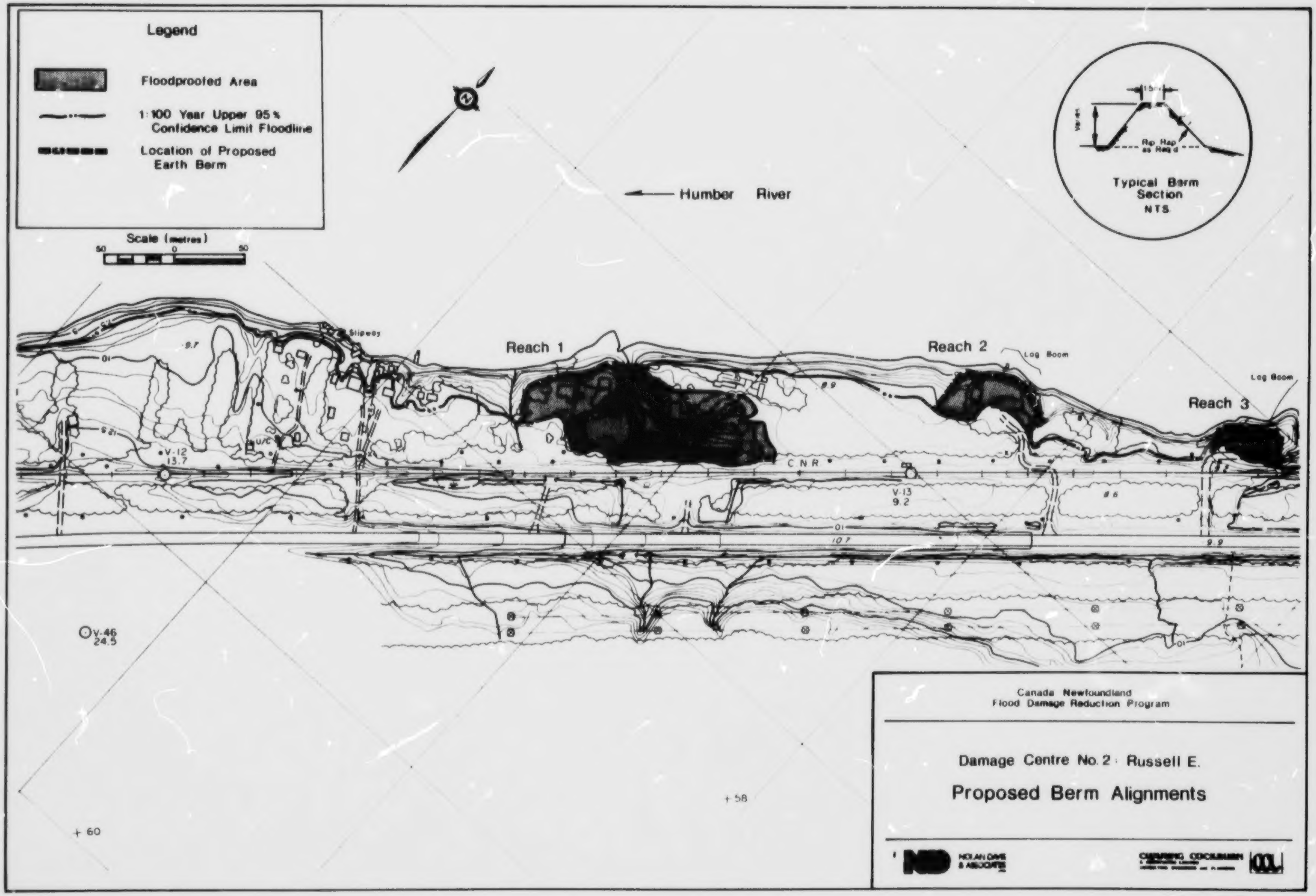
Figure 3.5


Legend
Floodproofed Area
1:100 Year Upper 95 Confidence Limit Floodline
Proposed Raising of Roadway
Proposed Earth Berm
Scale (metres)
50
0
50
Humber River
Steady Brook
Flooded
Flooded
Pool
Pool
Piers
Log Boom
Tower
Weir U/C
Typical Berm Section
N.T.S.
1.5m
Varies to 2.5m
2:1
Rip Rap as Req'd
Holan Davis & Associates
Cumming Cockburn

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No 1: Steady Brook
Scheme 'E' Berm Alignment

Figure 3.6

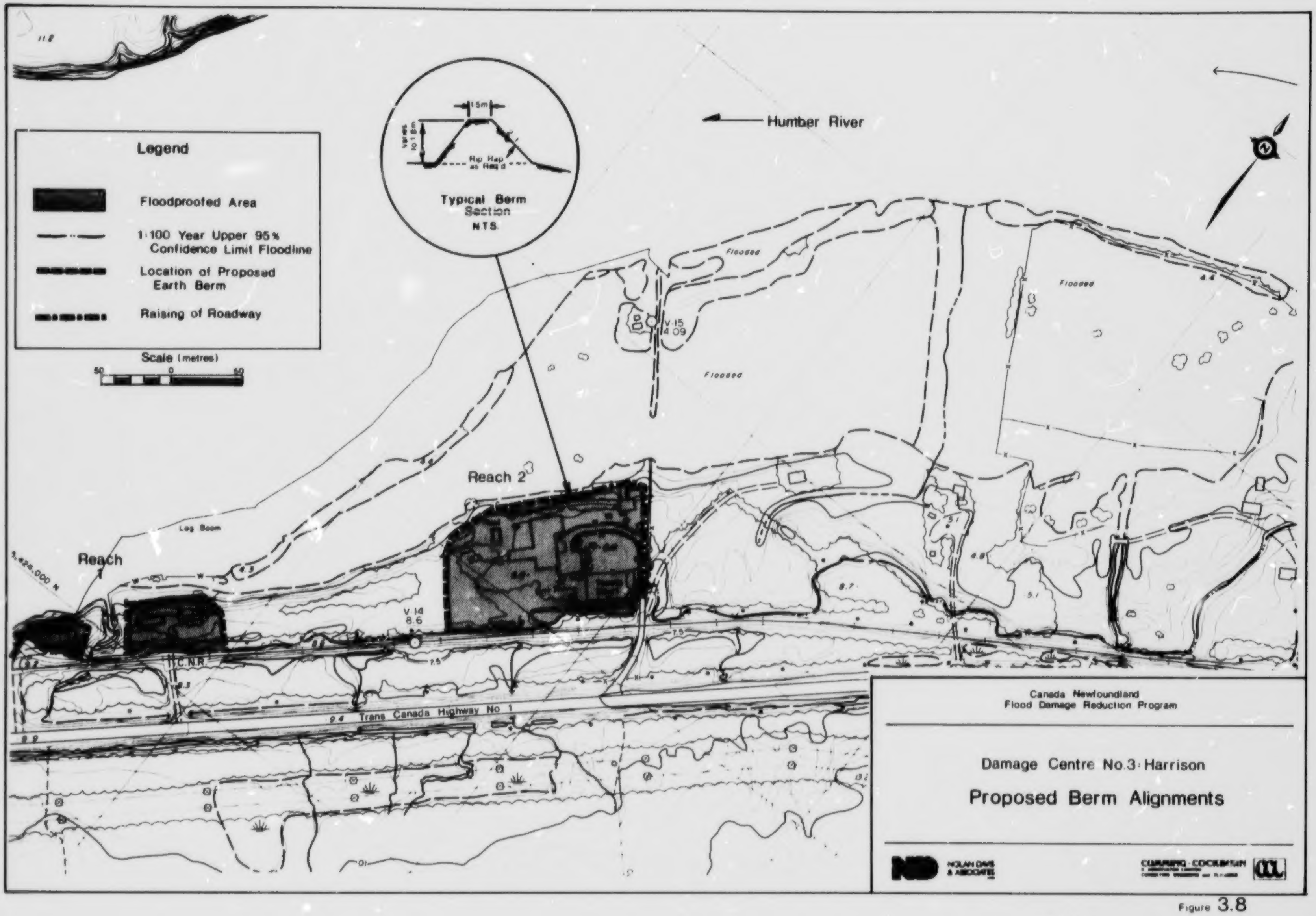

Legend
Floodproofed Area
1:100 Year Upper 95% Confidence Limit Floodline
Location of Proposed Earth Berm
Scale (metres)
50
0
50
N
Humber River
Typical Berm Section
NTS
Varies
1.5m
Rip Rap as Req'd
Slipway
Reach 1
Reach 2
Log Boom
Reach 3
Log Boom
9.7
01
9.21
V-12
13.7
U/C
CNR
V-13
9.2
8.9
8.6
01
10.7
9.9
V-46
24.5
+ 60
+ 58
01

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No. 2: Russell E.

Proposed Berm Alignments

Figure 3.7


Legend
Floodproofed Area
1:100 Year Upper 95% Confidence Limit Floodline
Location of Proposed Earth Berm
Raising of Roadway
Scale (metres)
50
0
50
Typical Berm Section
NTS
1.5m
Varies to 1.8m
Rip Rap as Req'd
Humber River
Flooded
Flooded
Flooded
V 15
4.09
V 14
8.6
Reach 2
Reach
Log Boom
5,424,000 N
C.N.R.
Trans Canada Highway No 1
11.2
4.4
7.5
9.4
9.9
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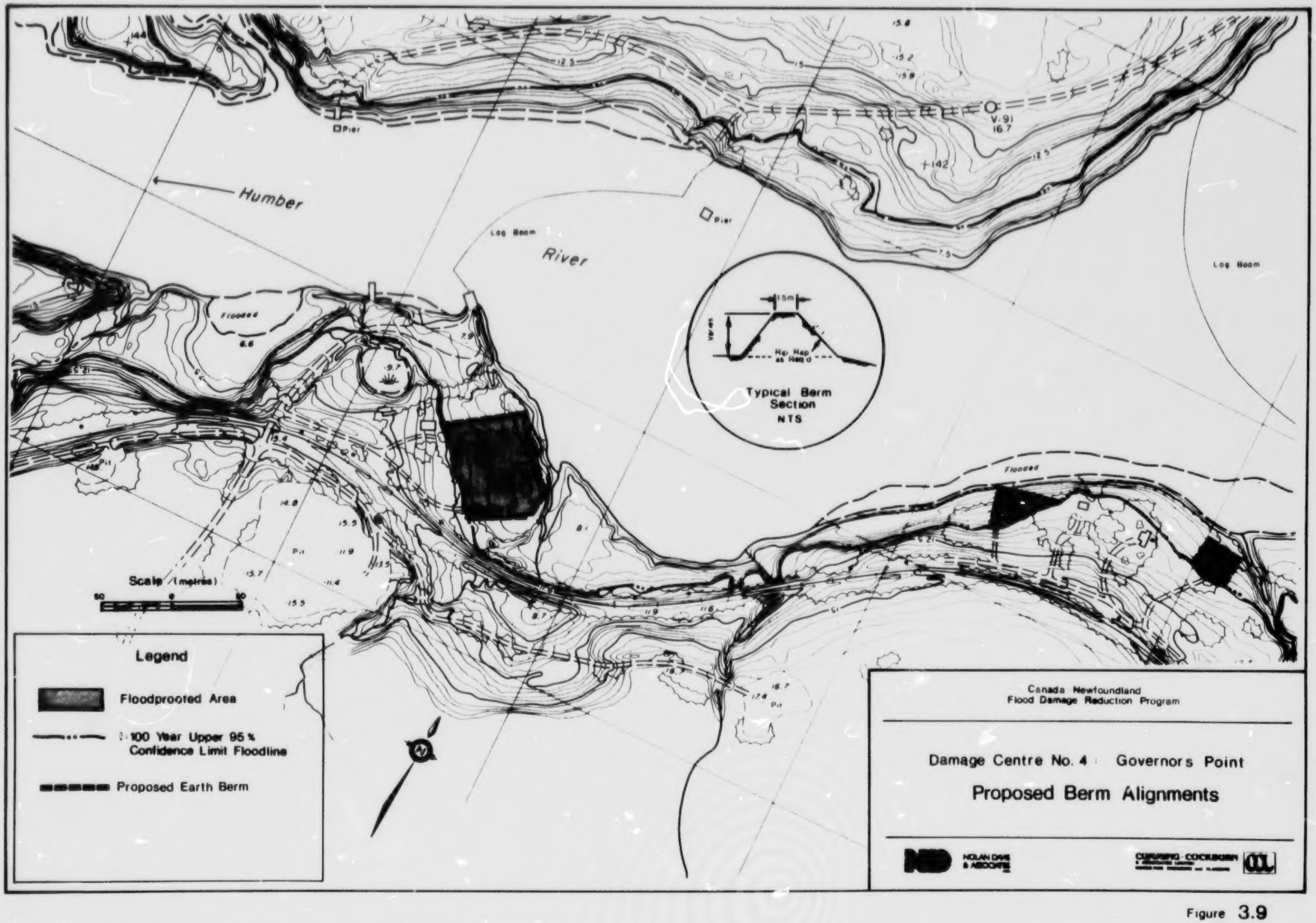
CUMMING COCKBURN

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No.3: Harrison

Proposed Berm Alignments

Figure 3.8

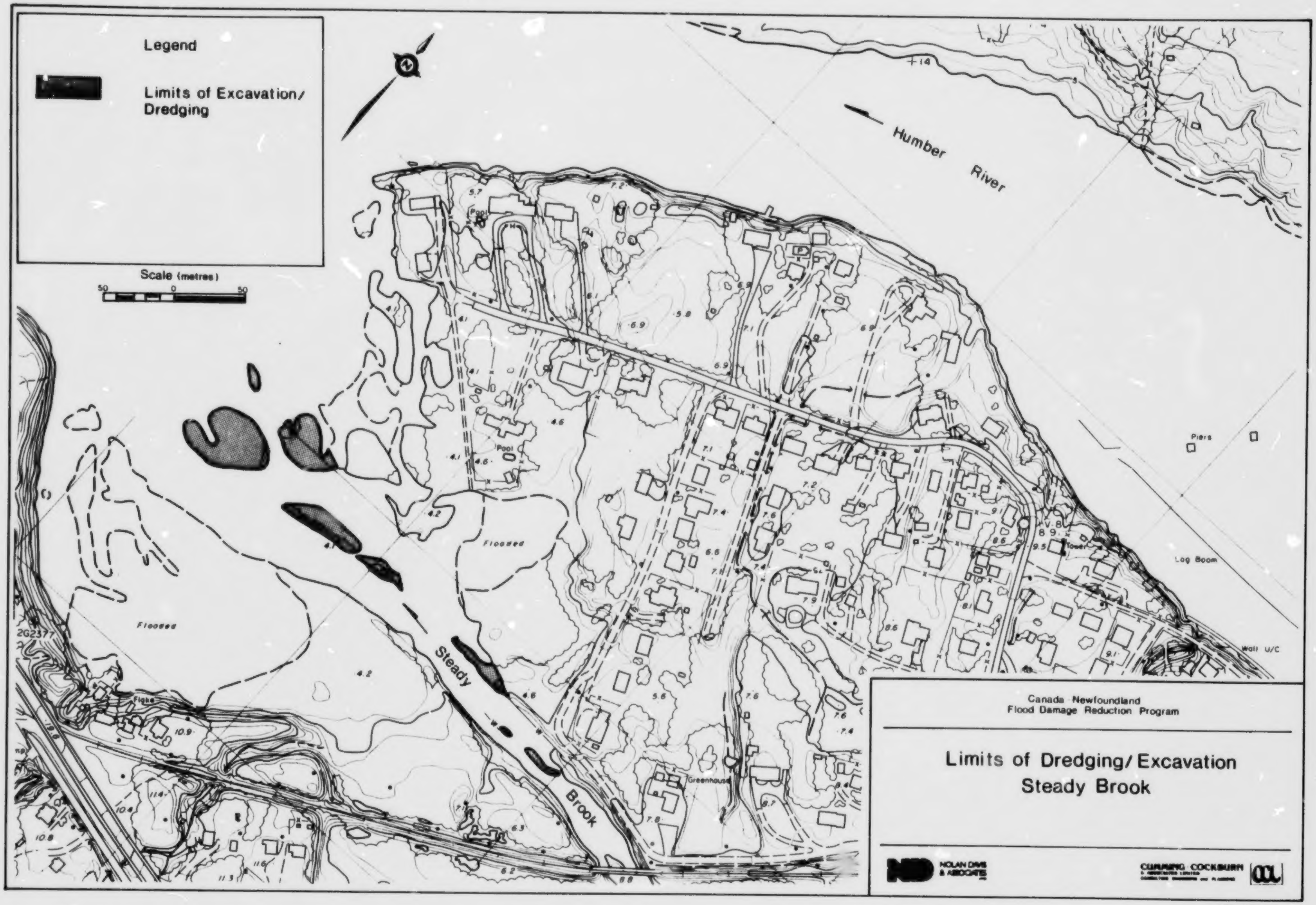

Humber
River
Log Boom
Log Boom
Pier
Pier
Flooded
Flooded
V-91
16.7
+142
Typical Berm
Section
NTS
1.5m
Varies
Rip Rap
as Req'd
Pit
Pit
Pit
Scale (metres)
50
0
50
Legend
Floodproofed Area
1:100 Year Upper 95 %
Confidence Limit Floodline
Proposed Earth Berm

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No. 4 : Governors Point

Proposed Berm Alignments

Figure 3.9


Legend
Limits of Excavation/ Dredging
Scale (metres)
50
0
50
Humber River
Steady Brook
Flooded
Flooded
Pool
Pool
Greenhouse
Piers
Log Boom
Wall U/C
+14
2G2377

Canada Newfoundland
Flood Damage Reduction Program

Limits of Dredging/ Excavation
Steady Brook

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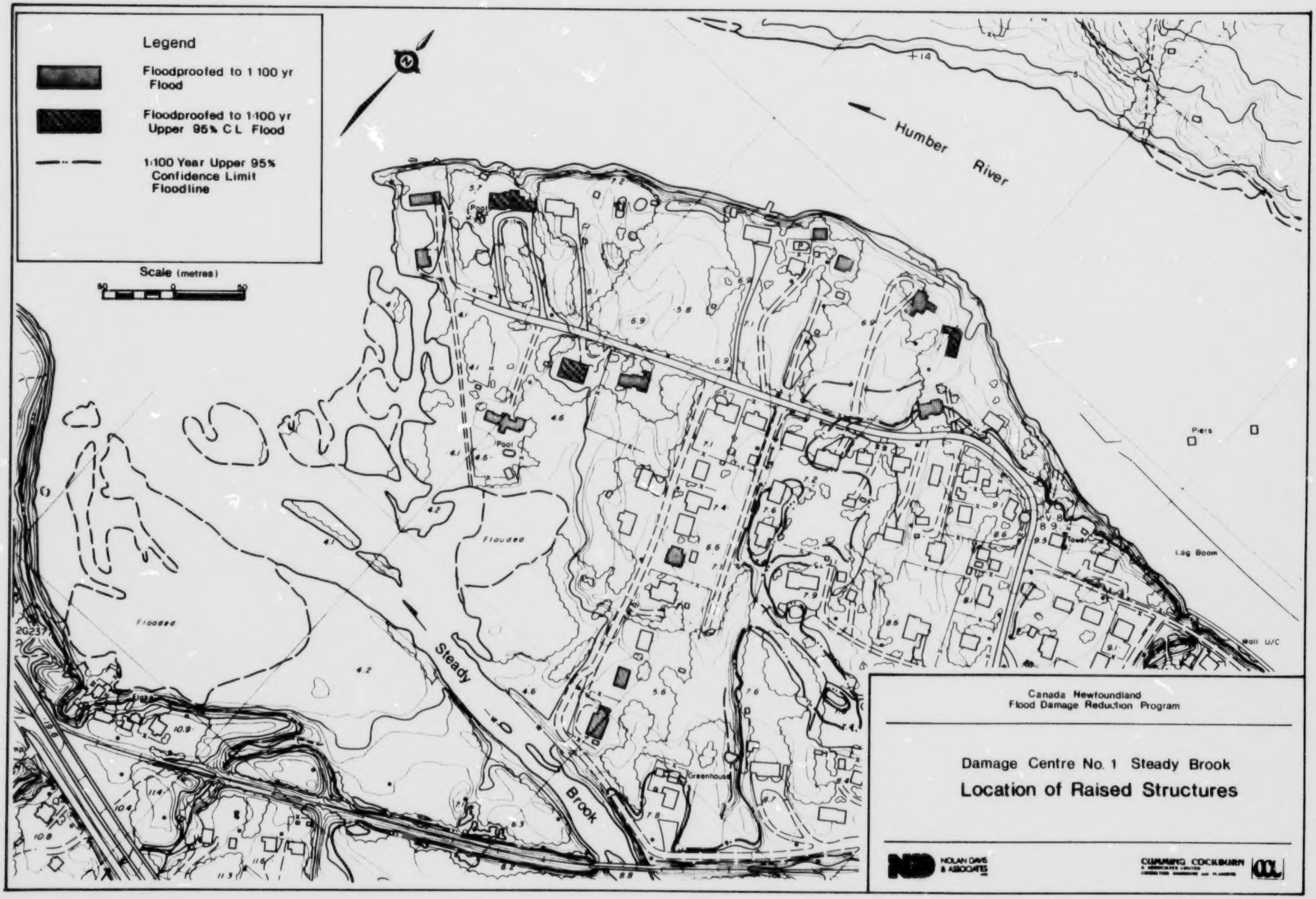
Figure 3.10

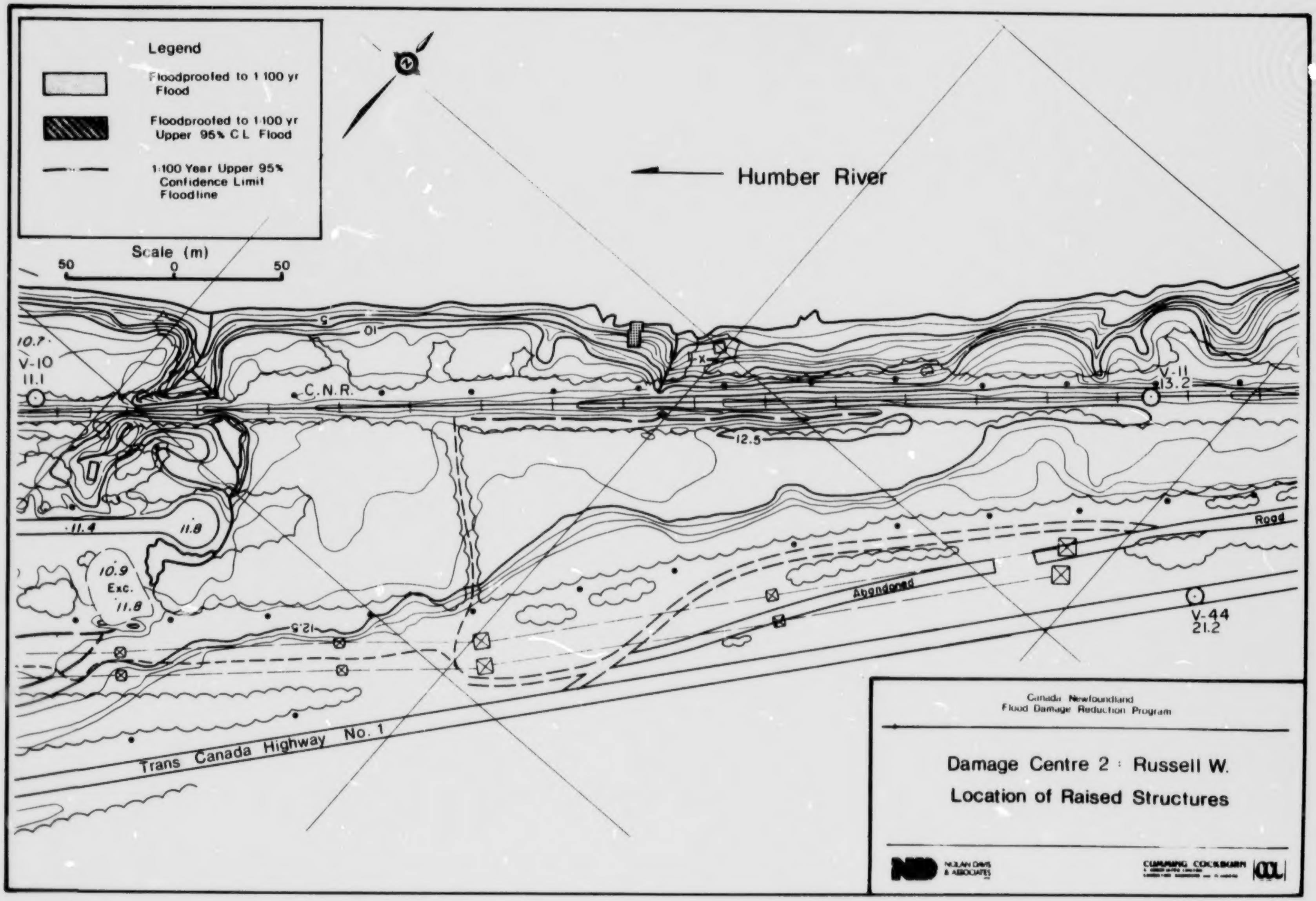


Legend
▨ Floodproofed to 1:100 yr Flood
▨ Floodproofed to 1:100 yr Upper 95% C.L. Flood
1:100 Year Upper 95% Confidence Limit Floodline
Scale (metres)
50
0
50
Humber River
Steady Brook
Flooded
Flooded
Pool
Pool
Greenhouse
Piers
Log Boom
Wall U/C
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN & ASSOCIATES LIMITED

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No. 1 Steady Brook
Location of Raised Structures

Figure 3.11


Legend
Floodproofed to 1:100 yr Flood
Floodproofed to 1:100 yr Upper 95% C.L. Flood
1:100 Year Upper 95% Confidence Limit Floodline
Scale (m)
50
0
50
Humber River
C.N.R.
V-10
11.1
10.7
V-11
13.2
V-44
21.2
5
10
12.5
11.4
11.8
10.9
Exc.
11.8
12.5
Road
Abandoned
Trans Canada Highway No. 1
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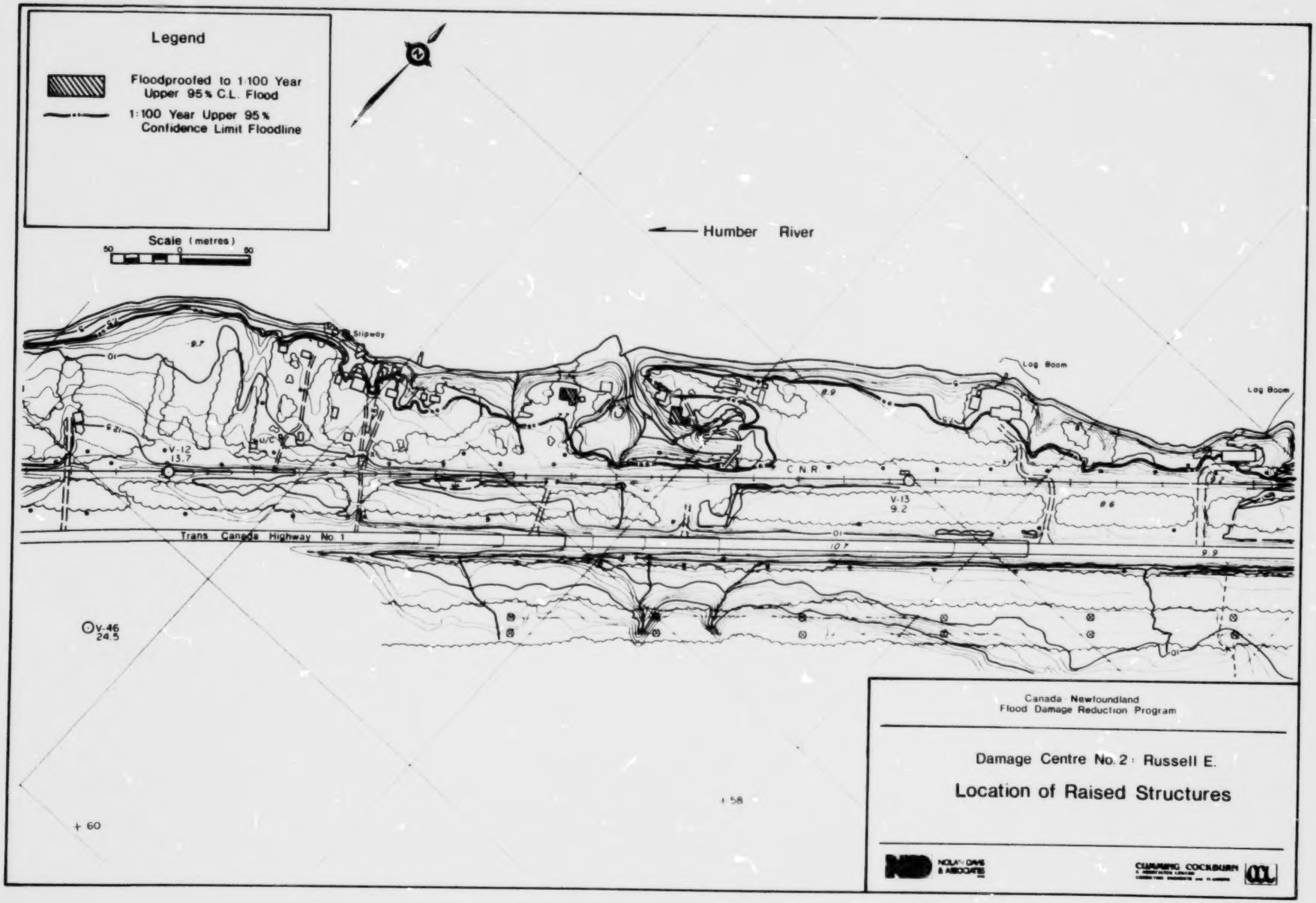
Damage Centre 2 : Russell W.
Location of Raised Structures

Figure 3.12


Legend
▨ Floodproofed to 1:100 Year Upper 95% C.L. Flood
1:100 Year Upper 95% Confidence Limit Floodline
Scale (metres)
50
0
50
Humber River
Slipway
Log Boom
Log Boom
C.N.R.
V-12
13.7
V-13
9.2
V-46
24.5
Trans Canada Highway No. 1
+ 60
+ 58

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Flood Damage Reduction Program

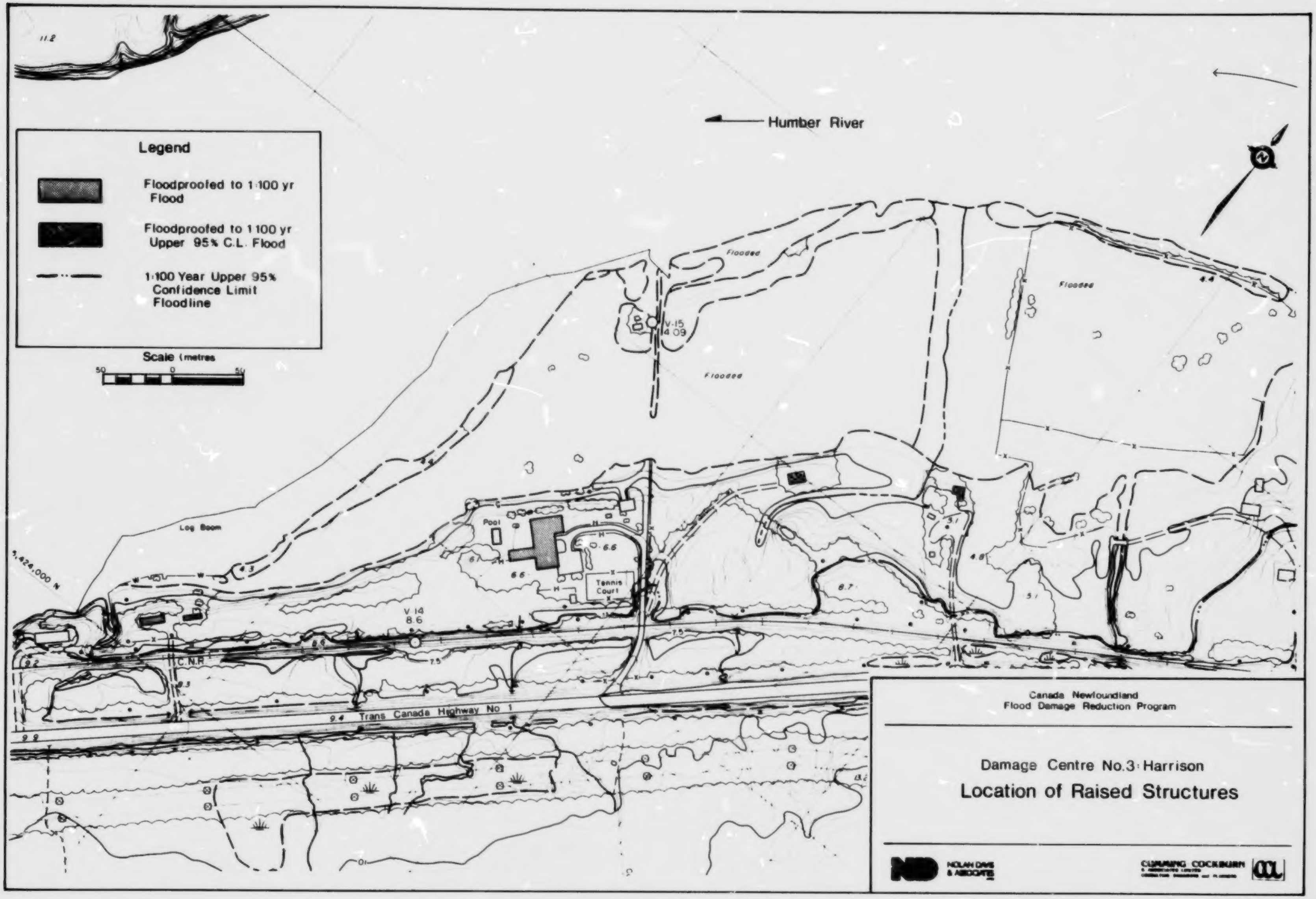
Damage Centre No. 2: Russell E.

Location of Raised Structures

Nolan, Davis & Associates

Cumming Cockburn

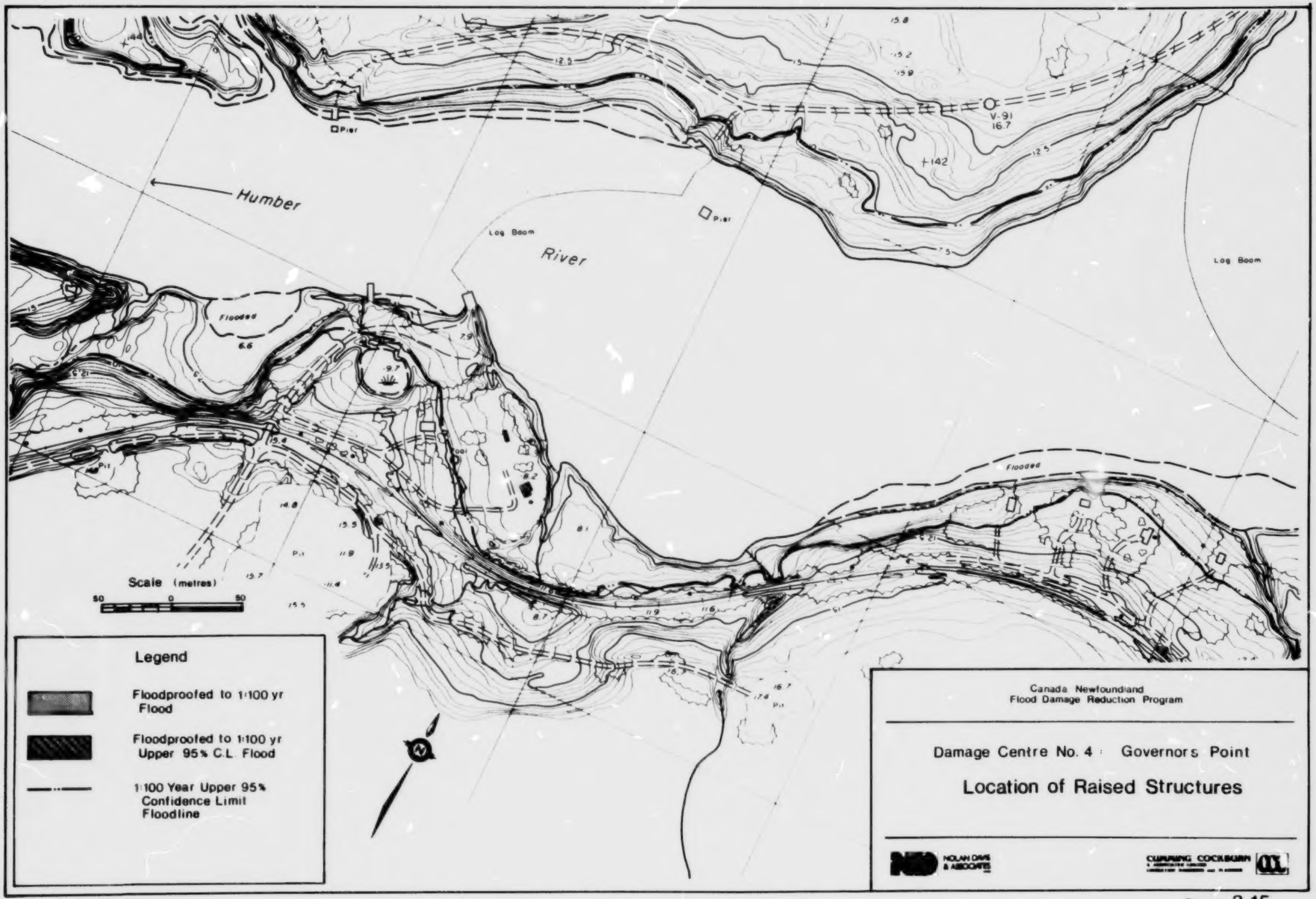
Figure 3.13


Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No.3: Harrison
Location of Raised Structures

Humber River
Legend
Floodproofed to 1:100 yr Flood
Floodproofed to 1:100 yr Upper 95% C.L. Flood
1:100 Year Upper 95% Confidence Limit Floodline
Scale (metres)
50
0
50
Flooded
Flooded
Flooded
V-15
4.09
V-14
8.6
Log Boom
Pool
Tennis Court
C.N.R.
Trans Canada Highway No 1
5,424,000 N
11.2
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

Figure 3.14

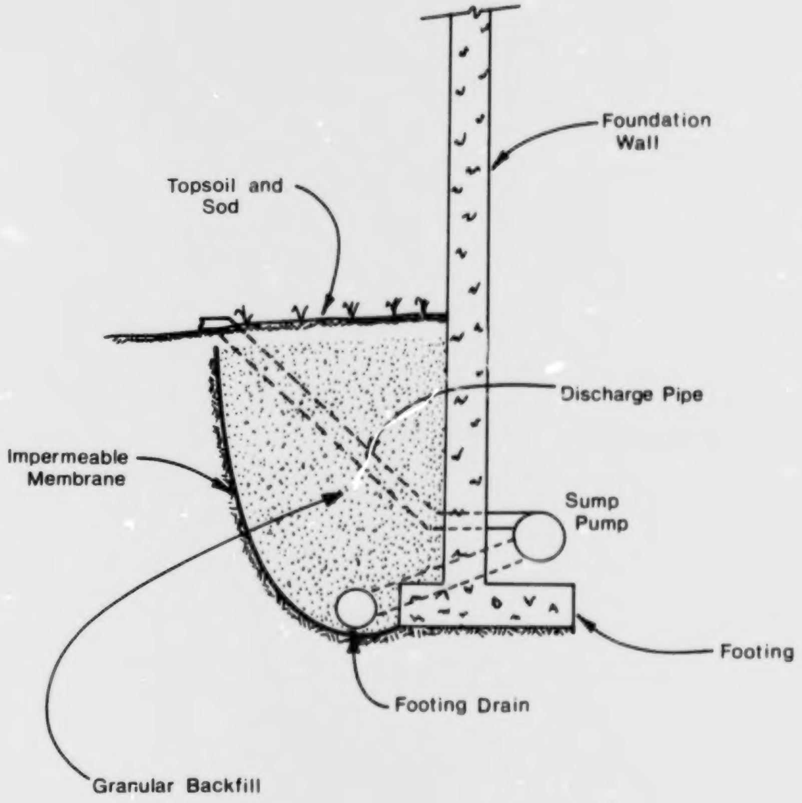

Humber
River
Log Boom
Log Boom
Pier
Pier
Flooded
Flooded
Pit
Pit
Pit
V-91
16.7
+142
12.5
15.8
15.2
15.9
6.6
9.7
7.9
8.2
8.1
8.7
11.9
11.6
14.8
15.5
15.7
11.4
16.7
17.4
Scale (metres)
50
0
50
Legend
Floodproofed to 1:100 yr Flood
Floodproofed to 1:100 yr Upper 95% C.L. Flood
1:100 Year Upper 95% Confidence Limit Floodline
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

Canada Newfoundland
Flood Damage Reduction Program

Damage Centre No. 4 : Governors Point

Location of Raised Structures

Figure 3.15


Foundation Wall
Topsoil and Sod
Discharge Pipe
Impermeable Membrane
Sump Pump
Footing
Footing Drain
Granular Backfill

Canada - Newfoundland
Flood Damage Reduction Program

Alternate Foundation Drainage System

Figure 3.16

4.0 SELECTED METHODS OF FLOOD CONTROL FOR PHASE II ANALYSIS

The following remedial measures were considered to have sufficient potential benefits to warrant a more in-depth analysis;

Scheme 1 - Status Quo
Scheme 2 - Floodproofing/Raising of Structures.

In addition, in our opinion it was felt that some channel improvements (dredging) should be given further consideration at the mouth of Steady Brook in order to improve ice jam conditions. While not found to be economically viable, such improvements would reduce the potential for personal injury and loss of life in addition to lowering flood damage.

Specific details of the above schemes and their impact on the flooding condition are addressed in Section 6.0, under the Phase II component of these investigations.

Phase II:
Detailed Evaluation of Selected Schemes

5.0 INTRODUCTION TO PHASE II

5.1 General

In Phase I, the following investigations were undertaken in regard to identification of remedial measures:

- the causes of flooding as identified in previous studies (7,8,9, 11,21,22) were summarized and stage-frequency relationships developed (see Section 2.5)
- a preliminary estimate of potential damages was determined and representative stage-damage curves were developed (refer to Figure 2.6 and Appendix B)
- damage-frequency relationships were developed, including the identification of frequent and infrequent flood levels, and estimates of average annual damages were computed (see Table 2.2)
- a wide range of potential measures to alleviate the existing flood risk were considered. The various structural and non-structural remedial work schemes practical for evaluation to the study area are addressed in Section 3.0, including preliminary benefit-cost analyses.
- recommendations were made for further study of selected alternatives in Phase II, as listed in Section 4.0.

5.2 Overview of Phase II Methodology

The analysis and recommendations derived from Phase I of this investigation were reviewed by the Technical Committee of the Canada-Newfoundland Flood Damage Reduction Program. The following remedial measures were identified for further consideration:

- discuss the implications of the "status quo" alternative in view of current FDRP policies and compensation for future flood losses
- refine the analysis of floodproofing/raising of structures within the 1:100 year flood risk area to reduce flood damages

- examine further the potential benefits regarding channel improvements (dredging) for partial protection against open water and ice related floods at the mouth of Steady Brook.

The preliminary investigations have indicated that none of the alternatives would completely prevent flood damages for large flood events. However, it was found that some economic benefits can be attained, including protection from more frequent flood events. Some further refinement and analysis of the structural alternatives is given in Section 6.1 and the non-structural measures in Section 6.2.

6.0 FINAL ASSESSMENT OF REMEDIAL MEASURES

6.1 Structural Measures

6.1.1 General

The following structural measures for reducing flood damages were considered in further detail during Phase II:

- Floodproofing/Raising of Structures
- Channel Improvements/Dredging

It should be noted that these schemes provide a varying degree of protection against the magnitude of future flood events, as noted in the following discussion.

6.1.2 Floodproofing/Raising of Structures

The Phase I investigations illustrated that the raising of the first floor elevation of affected homes above the 1:100 year design flood level would be a feasible alternative. Therefore, a detailed structure by structure evaluation was undertaken dependent on:

- the ease of undertaking the scheme given the accessibility of the structure to provide for raising
- size and type of building (i.e. full foundation/basement, pier type footings, etc.)
- structural stability of the building and site conditions
- relative ease of upgrading the servicing to the structure as a result of the undertaking
- aesthetic impact and landscaping requirements of the scheme.

For those structures with basements or foundation walls, the conceptual design and construction costs provide for raising the first floor/ basement floor an equivalent amount and the installation of sump pumps.

For structures without foundation walls or basements, the cost simply involves the raising of the structure and increasing the height of the support structure.

While the raising of structures would protect dwellings from experiencing first floor flooding, it would not eliminate flooding of basements due to overland or groundwater flow. As a result, the raising of structures does not guarantee absolute flood protection against all storm events. In order to increase the level of protection, additional floodproofing measures would be required.

To reduce flooding by overland flow, the sealing of low water entry points was considered. One of the most cost-effective measures is to place an additional fixed window pane over all low water entry points. If properly installed and sealed, this would prevent basement flooding by overland flow. Furthermore, for those structures where raising is impractical, or where existing damages are not related to first floor flooding, adoption of this type of floodproofing measure would eliminate most flood damages resulting from overland flow.

However, as identified in Phase I, flooding due to groundwater is also a contributing factor to damages in Steady Brook. Independent assessments of each structure would be required to examine the groundwater problem. Such an investigation was beyond the scope of this study. For this reason, no further evaluation of methods to alleviate groundwater flooding were addressed and some ongoing flood losses from this source can be expected.

A summary of the structures affected, and optimized methodology to be applied, is given in Table 6.1 and illustrated on Figure 6.1. The associated costs of these works can be found in Table 6.2. A typical sketch which describes the methodology for the floodproofing/raising of structures is given on Figure 6.2.

On the basis of economics only, the most attractive structural scheme for alleviating flood damages is floodproofing and raising of structures in Steady Brook (Damage Centre No. 1) and Harrison (Damage Centre No. 3). None of the structural benefits examined had a positive economic benefit for the Russell or Governors Point reaches, Damage Centres No. 2 and 4 respectively.

6.1.3 Channel Improvements/Dredging for Ice Protection

To minimize the potential for ice jam occurrences along the downstream reach of Steady Brook, removal of existing obstructions (such as the Steady Brook Swimming Pool piers) in conjunction with channel excavation and dredging of the numerous shoals and islands at the mouth was considered.

Previous research completed on ice jams indicate that changes in slope can be conducive to ice jams (5, 6, 18). Similarly, channel constraints such as the islands and man-made obstacles, combined with the limited, non-uniform cross-sectional depth have been found to contribute to the frequency of ice jams observed in the Steady Brook channel.

Dredging of the channel and removal of the numerous islands and shoals at the mouth of Steady Brook would reduce the potential for ice jam formation at this location. Provided the Humber River remains ice free and is not under a high stage condition during breakup, the channel improvements would promote hydraulic conditions (i.e. increased channel area, depth, lower velocities, etc.) leading to stable ice accumulations and movement at the mouth of Steady Brook.

The total volume of dredging required to create a stable ice cover would be about 14,100 m^3. This is based on the extent of excavation as shown on Figure 6.3.

The existing condition, where jamming is known to occur and flooding a certainty, and proposed conditions discussed above, represent two extreme conditions. Many factors influence the probability of jam formation, such as rate of increase and peak discharge, ice volume and strength, rate of inflow, transport capability of the flow downstream from the lodgement point and ice characteristics.

A significant change in the uniformity of cross-sectional geometry and area of the channel bed would result under this scheme, reducing the potential for grounding of ice and ice jamming. However, ice jams would not be completely alleviated due to the nature of the Brook (i.e. rapid transition of flow, effects of the Humber River). Similarly, changes in Froude indices, etc. cannot be quantitatively determined due to the uncertainty of the backwater effects of the Humber River at the time of breakup. While Froude numbers would be lowered as a result of dredging, it is unlikely that they would ever be below the critical value of 0.08. Lack of adequate meteorological and ice monitoring data also complicates the provision of any absolute remedial scheme with respect to associated benefits.

For the purpose of this evaluation, and in order to examine the "ultimate benefit" of the scheme to reduce ice related flooding, it is assumed that all contributing factors are conducive to the optimum elimination of ice jams. Assuming this ultimate scenario in conjunction with the proposed channel improvements, the resultant benefit would be complete flood protection to the Steady Brook community under the 1:100 year event. (Assumes that the event is independent of flooding on the Humber River.)

The cost of the channel dredging and improvements was estimated as $160,300, as given in Table 6.3. The resulting benefits and a comparison to the estimated project costs in terms of their present value is discussed in Section 7.0. A typical sketch illustrating the extent of the proposed work and typical post-construction cross-sections can be found on Figure 6.3. This configuration would increase the mean hydraulic depth and channel storage area at the outlet of Steady Brook which would lessen the severity of any future flood impacts associated with ice events to the area.

6.2 Non-structural Measures

6.2.1 General

The non-structural measures selected for further evaluation in Phase II consisted of the:

- Floodplain management policy (implement as per Section 3.3.4)
- "Status Quo"

Neither of these measures will prevent future flooding to the study area.

6.2.2 Status Quo

The maintenance of the status quo assumes that the flood hazard which presently exists within the study area would remain unchanged. No structural or non-structural schemes would be introduced for damage reduction.

This approach assumes that compensation for flood losses would be provided by the government. Therefore, the ultimate cost benefit ratio for this scheme would equal 1.0 (i.e. all flood damages experienced would be compensated for). The costs associated with flooding are evaluated based on each independent event, and would vary from year to year. This approach is viable only where the cost-benefit ratio of all other measures is not attractive.

While in economic terms the maintenance of the status quo may prove attractive compared to other schemes, the existing social and environmental hazards still remain.

6.2.3 Floodplain Zoning

The 1:20 and 1:100 year flood limits have been designated by the Province of Newfoundland and the Government of Canada in Steady Brook.

Floodplain management policies should be adopted by the Community as described in Section 3.3.4. Floodplain zoning should be implemented in order to minimize the potential for increasing continued development and associated damages in floodplain areas (see Section 3.3.4). By taking this action, the magnitude and periodicity of flooding should remain essentially unchanged with time.

TABLE 6.1

Phase II

Summary of Floodproofing/Raising of Structure Schemes (1)

Damage Centre No.	House No./ Location	Floodproofing Measure	Level of Protection(2) of Remedial Work 1:100 Yr	Other
1	Steady Brook:			
	1 Brook Rd.	Seal low water openings & provide sumps	x	
	2 " "	" " " " " " "	x	
	11 Falls Ave.	" " " " " " "	x	
	15 " "	" " " " " " "	x	
	17 " "	Raise first floor by 0.1 m	x	
	17B " "	" " " " 0.7 m	x	
	1 Forest Dr.	Seal low water openings & provide sumps		Approx 1:70 yr
	1B " "	Raise first floor by 0.4 m	x	
	2 " "	" " " " 0.4 m	x	
	4 " "	" basement & first floor by 0.7 m. Seal low water openings & provide sumps	x	
	6 " "	" " " " " " "	x	
	7 " "	" " " " " " "	x	
	15 " "	" " " " " " "	x	
	17 " "	" " " " " " "	x	
2	Russell:			
	1	Raise first floor by 0.3 m, seal	x	
	11	" " " " 0.5 m, "	x	
	12	" " " " 0.5 m, "	x	
3	Harrison:			
	4	Raise first floor by 0.1 m	x	
	6	" " " " 0.6 m	x	
	7	" " " " 1.0 m		Approx. 1:50 yr
4	Governors Point:			
	1	Raise first floor by 0.4 m	x	
	2	" " " " 0.2 m	x	

(1) Only those structures warranting remedial measures are included herein. See also Table 3.5 for additional details.

(2) All damages eliminated for flood events equal in, or less than, a magnitude of the recurrence interval noted.

TABLE 6.2

PHASE II

Cost Estimate Summary

Floodproofing/Raising of Structures

Component	Item	Description	Quantity	Unit Cost ($)	Total ($)
Damage Centre 1 : Steady Brook					
Structure Raising	1	Mobilization	4	1,000	4,000
	2	Excavation/backfill	1	600	600
	3	Increase height of existing foundation wall	120 m^2	40	4,800
	4	Install basement subfloor	1	2,000	2,000
	5	Raising of dwelling	4	3,000	12,000
	6	Landscaping	4	500	2,000
Flood-proofing	7	Installation of watertight window unit (1)	11	1,500	16,500
		Sub-total			41,900
		Contingency			4,200
		TOTAL			$ 46,100

TABLE 6.2 (cont'd)

Component	Item	Description	Quantity	Unit Cost ($)	Total ($)
Damage Centre 2 : Russell					
Structure Raising	1	Mobilization	3	1,000	3,000
	2	Excavation/backfill	3	600	1,800
	3	Increase height of existing foundation wall	60 m^2	40	2,400
	4	Install basement subfloor	3	2,000	6,000
	5	Raising of dwelling	3	3,000	9,000
	6	Landscaping	3	500	1,500
Flood-proofing	7	Installation of watertight window unit (1)	3	1,500	4,500
		Sub-total			19,200
		Contingency			1,900
		TOTAL			$ 21,100
Damage Centre 3 : Harrison					
Structure Raising	1	Mobilization	3	1,000	3,000
	2	Increase height of existing foundation wall	120 m^2	40	4,800
	3	Raising of dwelling	3	3,000	9,000
	4	Landscaping	3	500	1,500
		Sub-total			18,300
		Contingency			1,800
		TOTAL			$ 20,100

TABLE 6.2 (cont'd)

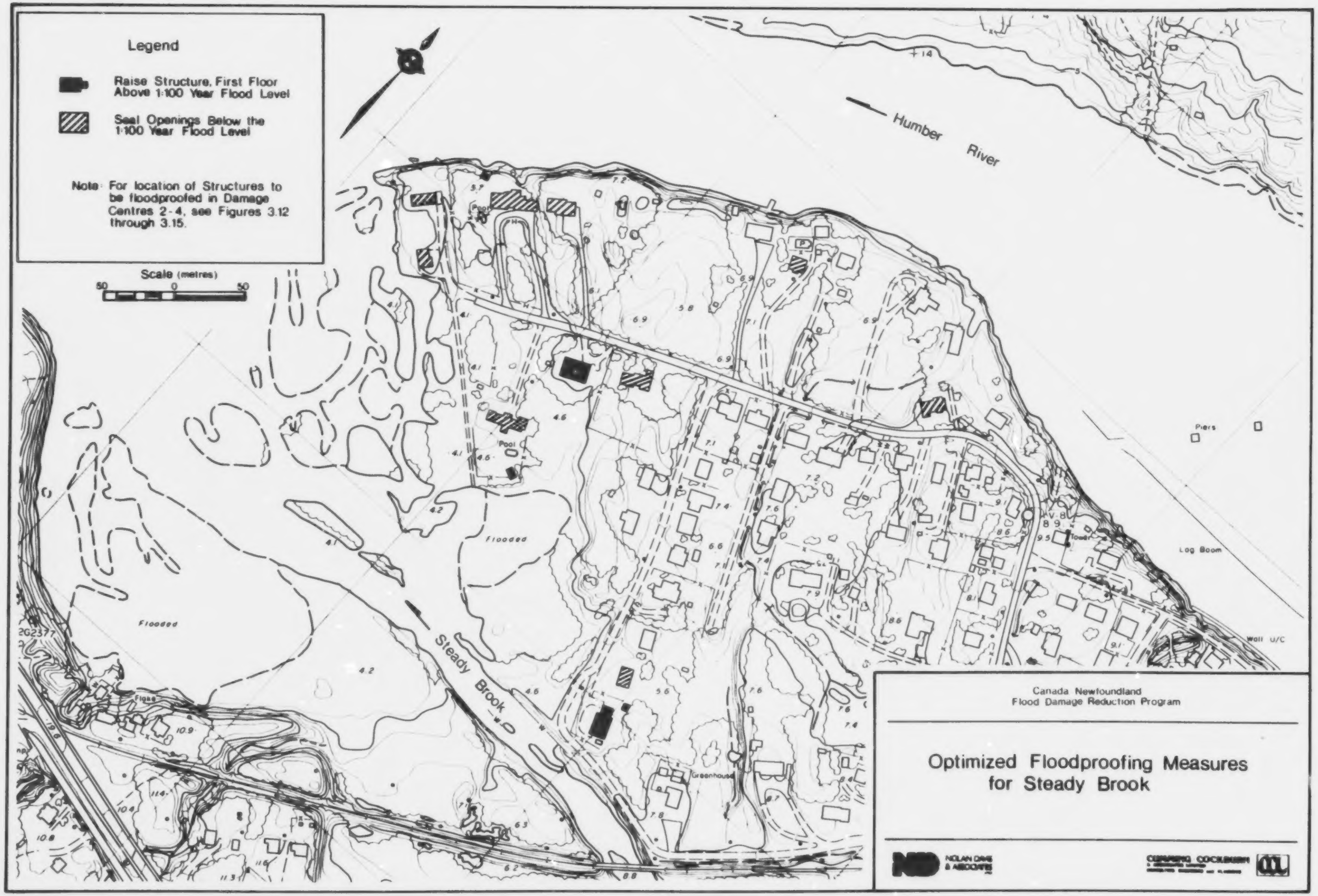
Component	Item	Description	Quantity	Unit Cost ($)	Total ($)
Damage Centre 4 : Governors Point					
Structure Raising	1	Mobilization	2	1,000	2,000
	2	Excavation/backfill	1	600	600
	3	Increase height of existing foundation wall	30 m^2	40	1,200
	4	Install basement subfloor	1	2,000	2,000
	5	Raising of dwelling	2	3,000	6,000
	6	Landscaping	2	500	1,000
Flood-proofing	7	Installation of watertight window unit (1)	1	1,500	1,500
		Sub-total			$ 14,300
		Contingency			1,400
		TOTAL			$ 15,700

(1) Based on an average of 4 windows per structure

TABLE 6.3
PHASE II
Cost Estimate Summary
Channel Improvements/Dredging

Item	Description	Quantity	Unit Cost ($)	Total ($)
1	Mobilization	Lump Sum	8,000	8,000
2	Removal of Channel Constrictions	14,100 m^3	$8 per m^3	112,800
3	Removal of Swimming Pool Piers	Lump sum	1,500	1,500
4	Maintenance Cost (1)	N/A	N/A	10,000
	Sub-total			132,300
	Contingency			13,000
	Engineering & Site Supervision			15,000
	TOTAL			$160,300

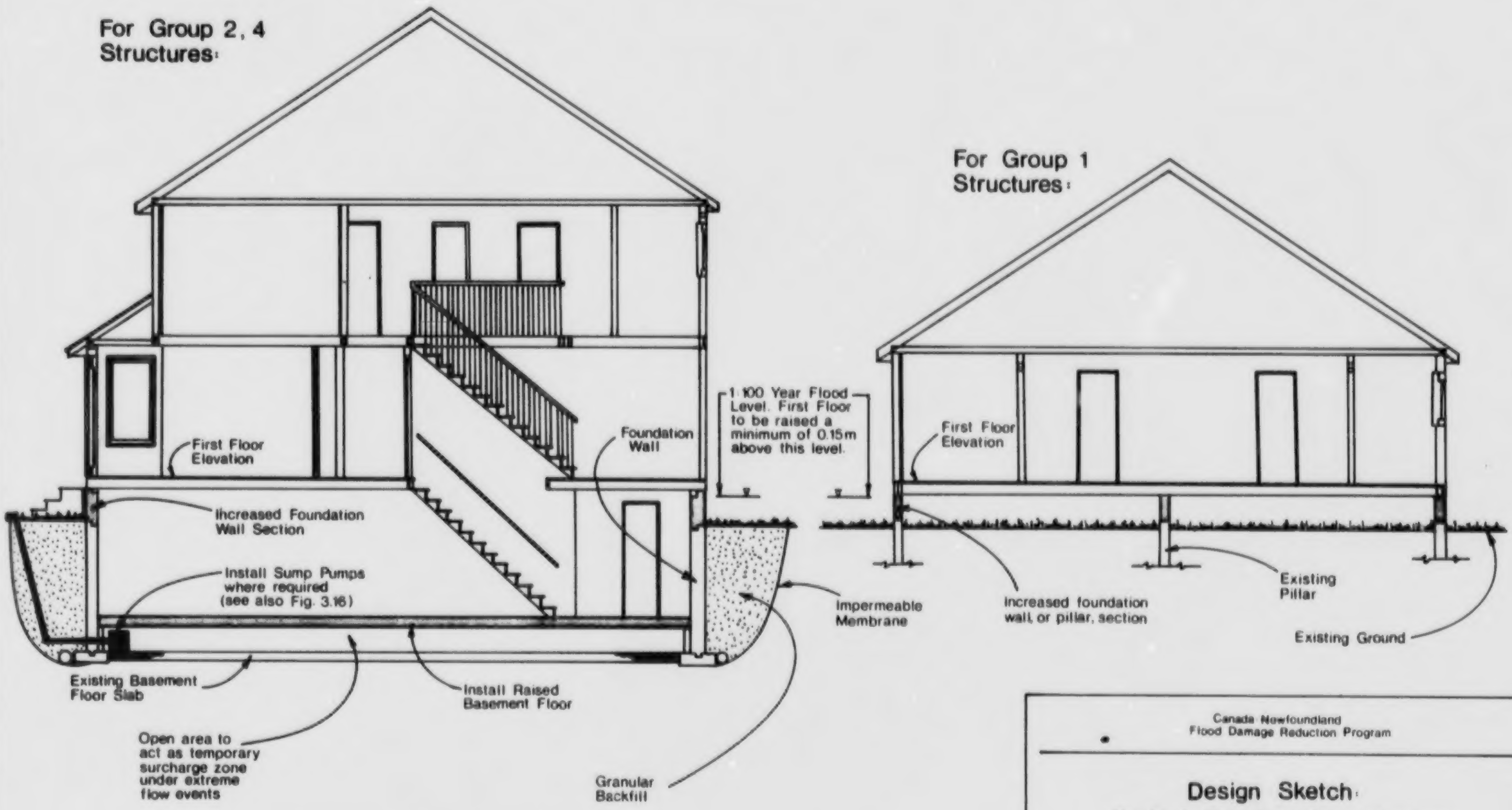
(1) Maintenance cost based on an annual cost of $1,000, amortized over the project life.


Legend
Raise Structure, First Floor Above 1:100 Year Flood Level
Seal Openings Below the 1:100 Year Flood Level
Note: For location of Structures to be floodproofed in Damage Centres 2-4, see Figures 3.12 through 3.15.
Scale (metres)
50
0
50
Humber River
Steady Brook
Flooded
Flooded
Pool
Pool
Piers
Log Boom
Wall U/C
Greenhouse
Flake
Tower
2G2377
NOLAN DAVIS & ASSOCIATES
CUMMING COCKBURN

Canada Newfoundland
Flood Damage Reduction Program

Optimized Floodproofing Measures for Steady Brook

Figure 6.1


For Group 2, 4
Structures:
First Floor Elevation
Increased Foundation Wall Section
Install Sump Pumps where required (see also Fig. 3.16)
Existing Basement Floor Slab
Install Raised Basement Floor
Open area to act as temporary surcharge zone under extreme flow events
Foundation Wall
Granular Backfill
Impermeable Membrane
1:100 Year Flood Level. First Floor to be raised a minimum of 0.15m above this level.
For Group 1
Structures:
First Floor Elevation
Increased foundation wall, or pillar, section
Existing Pillar
Existing Ground

Note: 1. All openings below 1:100 year flood elevation to be sealed water tight.

2. Not to be used for Construction Purposes

Canada Newfoundland
Flood Damage Reduction Program

Design Sketch:
Typical Floodproofing Measures

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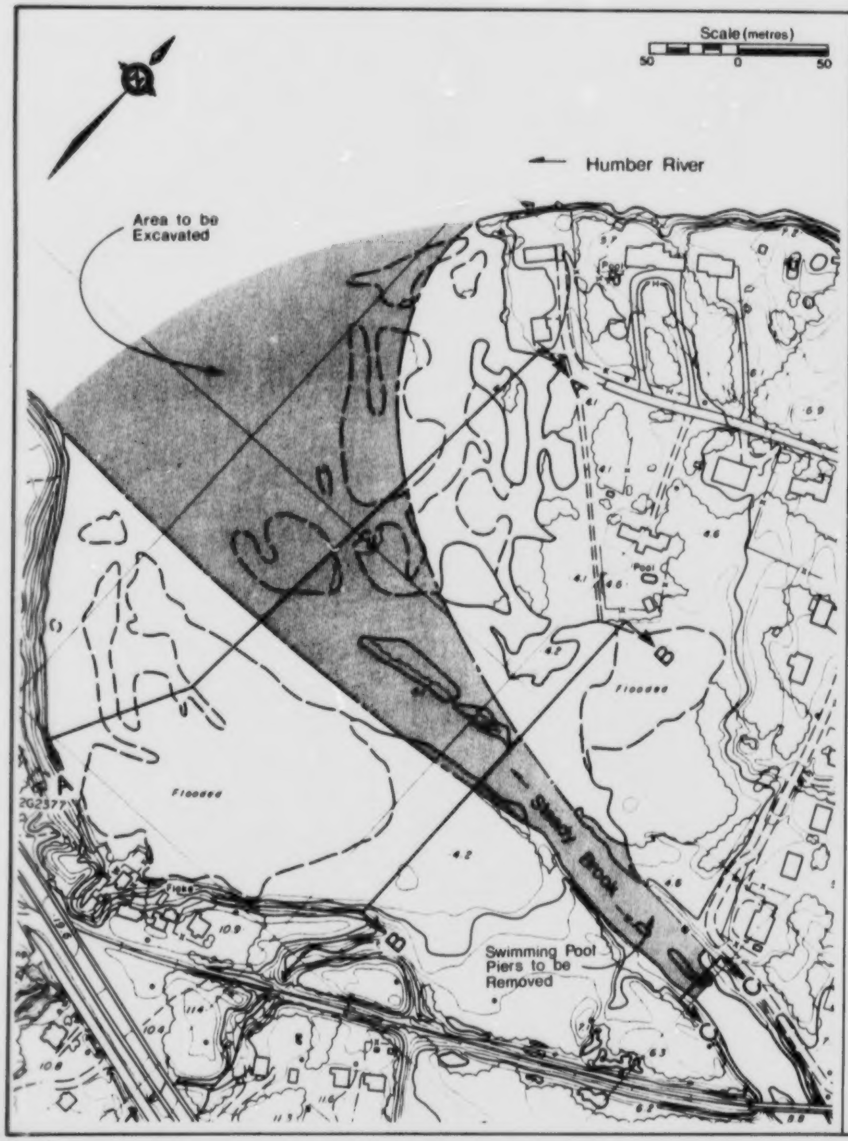
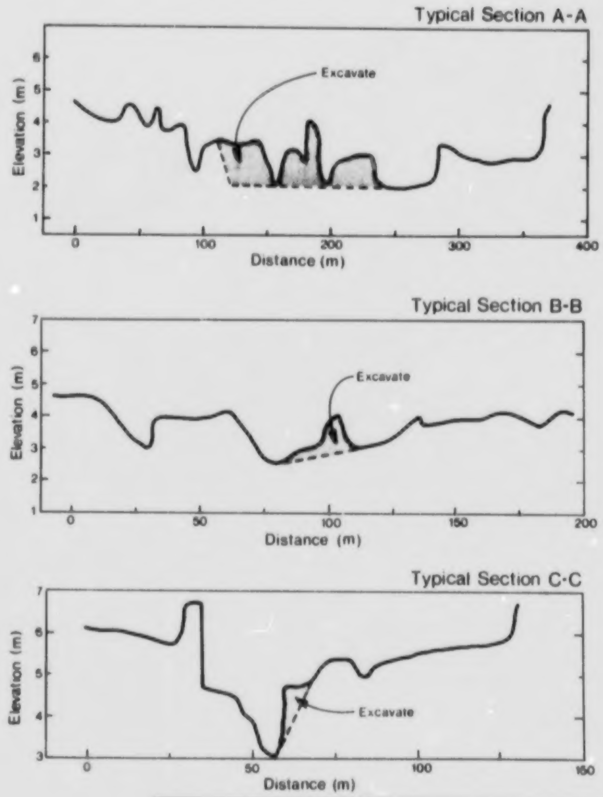
CUMMING COCKBURN

Figure 6.2


Scale (metres)
50
0
50
Humber River
Area to be Excavated
A
B
C
Pool
Flooded
Flooded
Steady Brook
Swimming Pool Piers to be Removed
2G2377



Canada Newfoundland
Flood Damage Reduction Program

Design Sketch
Channel Improvements/ Dredging

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CUMMING COCKBURN

Figure 6.3

7.0 FINAL COMPARISON OF REMEDIAL MEASURES

7.1 Final Benefit-Cost Analyses

The benefit-cost analyses from Phase I (see Section 3.0) have been updated to account for the improved cost estimates developed for the selected alternatives presented in Section 6.0. The sensitivity of the economics of each alternative with respect to the effective discount rate utilized was also considered. A discussion of the sensitivity testing can also be found in Appendix B. The results of these analyses are summarized in Table 7.1.

The methodology for the computations of the present worth of the benefits associated with each scheme is presented in Section 2.5, with additional details provided in Appendix B. The effective discount rate utilized in amortizing the average annual benefit to present worth was assumed to be 10%, based on guidelines set out by Environment Canada (12). To evaluate the sensitivity of the scheme in regard to the discount rate applied, a sensitivity analysis was carried out amortizing the average annual benefits to a present worth using effective discount rates of 5% and 15% (12). The benefit-cost analyses conducted are summarized in the following sections for each of the structural measures:

i) Floodproofing/Raising of Structures

The benefits for this scheme were based on providing flood protection for all storms up to the 1:100 year design flood level. Residual damages were estimated from Figure 2.6 and using the curves presented in Appendix B, assuming that damage below the 1:100 year flood elevation would be prevented where possible. Only improvements to primary dwellings were evaluated under this scheme (i.e. no remedial work undertaken on such structures as sheds, garages, etc.), however, the damage estimates included all structures susceptible to a flood risk. The benefit of a 1:100 year design level is the difference between the present worth of the average annual damages and any residual damages.

The economic analyses in all cases was based on a 50 year project life.

The revised costs for this scheme for each of the four damage centres were estimated as given in Table 6.2, with no provision for additional maintenance work required. These costs are slightly higher than those determined in Phase I due to the addition of floodproofing measures and information supplied by Newfoundland Department of Housing.

The final benefit-cost ratios for this scheme are given in Table 7.1, including a comparison of the sensitivity of these measures to the applied discount rate.

ii) Channel Improvements/Dredging

The benefits for this scheme were determined assuming total elimination of ice jams in the mouth of Steady Brook for peak discharge up to 1:100 years. This is an optimistic assumption since some ice jamming is still likely to occur.

As in the evaluation of floodproofing/raising of structures, the effective discount rate applied was 10%. (Sensitivity was subsequently conducted using effective discount rates of 5% and 15%.) The period of analysis was based on a 50 year project life.

Due to the uncertainty of sediment transport rates from the upstream reaches to the mouth of Steady Brook, an accurate prediction of the maintenance measures which will be required was not possible. For the purposes of this study, and based on our experience in conducting similar investigations on other watersheds, it was assumed that some maintenance dredging would be required over the project period of 50 years. The maintenance dredging cost was assumed to be about $1,000 per year, amortized over the project life (50 years), at the appropriate discount rate. The resulting present worth value of the maintenance cost was found to be $10,000, using a discount rate of 10%. This cost was reflected in the revised cost estimate for the scheme which can be found in Table 6.3. It should be noted that for the sensitivity testing, the maintenance cost reflects discount rates of 5% and 15% for uniformity of comparison.

The final "optimum" benefit-cost ratios for this scheme are given in Table 7.1 for the various discount rates evaluated. (These ratios represent an optimum condition which in all likelihood would not be achieved.) In our opinion, however, serious consideration should be given to undertaking this work in order to improve flow conveyance and minimize the potential for ice jams.

iii) Non-structural Measures

A strict benefit-cost analysis of the non-structural alternatives, is not feasible since, in our opinion, it is impossible to accurately predict the extent of flood damages affected by these schemes. While it is arguable that the status quo approach has an economic value, or benefit-cost ratio of 1.0, this assumes full compensation for all flood events will be made. In considering future development trends and the diversity in factors contributing to the flooding in the area, this may not always be the case. Furthermore, a tangible cost with respect to potential loss of life cannot be addressed. For contingency planning, the reduction in damages will depend in each case on the planning measures inacted and public response.

iv) Conclusions

The general conclusions of the final benefit-cost analyses, as evident from Table 7.1, are in keeping with the results found in Phase I. Of the options evaluated, only the floodproofing/raising of structures can be justified on an economic basis. In the other cases, the net economic benefits were found to be less than the associated costs for implementation.

Through examination of Table 7.1, it can be concluded that the benefit-cost analysis is sensitive to the discount rate selected. While the channel improvement/dredging scheme may appear to approach economic viability (B/C ratio of 0.97 for 15% discount rate), these numbers present an optimum condition not likely to be achieved. On the other hand, any reduction in the potential for ice jams will result in a corresponding reduction in the potential for associated loss of life or injury to local residents. Such flood losses cannot be measured in economic terms.

In terms of these economic benefits, the alternatives can be ranked as follows:

1. Floodproofing/Raising of Structures
2. Status Quo Approach
3. Floodplain Management Policy
4. Channel Improvements/Dredging

In addition to the above ranking, various other advantages and disadvantages of each flood mitigative measure should be considered, as discussed in the following section.

7.2 Advantages and Disadvantages of Selected Alternatives

The main advantages and disadvantages of the selected structural alternatives addressed in Section 6.0 can be summarized as follows:

i) Floodproofing/Raising of Structures:

Advantages

- the benefits associated with this scheme outweigh the associated costs (B/C >1.0)
- the existing groundwater problems to the Steady Brook community may be significantly reduced with the installation of sump pumps and raising of basement floors
- construction of this type of alternative would require very little disruption of the residential area in the floodplain
- only minor social impacts would result due to the implementation

of this scheme with respect to utilization of the river for recreation, or from an aesthetic point of view

- no disruption or impact in the natural environment would result from this scheme.

Disadvantages

- does not provide complete flood protection within the flood risk area
- inconvenience and restriction of access within the flooded area would still result under the scheme
- health related problems may persist given the lack of protection from surcharging of sewer system
- utilities and services in the area may continue to be affected under this scheme

ii) Status quo/floodplain management

Advantages

- limits/eliminates increases to the existing damage base
- the benefits associated with this scheme are equal to the associated costs (B/C = 1.0)
- no large initial capital outlay is required
- there is no cost to the local landowner
- the cost to government is dependent on a real event and may be less than those associated with a design remedial scheme over the equivalent project life (i.e. where the benefit/cost ratio for other measures is unfavourable)
- no disruption or impact to the existing social or natural environment would result

Disadvantages

- does not provide any form of flood protection within flood risk area

- inconvenience and restriction of access within the flooded area would still result under the scheme
- does not reduce risk to life associated with future flood events.

iii) Channel Improvements/Dredging

Advantages

- would significantly reduce the potential for ice jamming at the mouth of Steady Brook
- would add aesthetically to the community in terms of recreational use on the watercourse
- would result in only a temporary disruption to the residential community in the floodplain
- reduces potential for injury and/or loss of life due to sudden ice jams and flooding.

Disadvantages

- would not guarantee elimination of flooding due to ice jamming
- provides no real benefit in terms of reducing open water flooding in Steady Brook (i.e. flooding from Humber River)
- would result in a significant disruption to the aquatic environment in the area in terms of the benthic community and aquatic ecosystem
- would require further detailed study prior to implementation and undertaking of such a scheme.

TABLE 7.1

PHASE II Benefit-Cost Analyses

Summary of Benefit-Cost Analysis for Selected Schemes

Scheme	Damage Centre No.	Location	Discount Rate (%)	Existing Condition Damage ($)		Total Damage Under Proposed Scheme ($)	Total Benefit ($)	Cost ($)	Net Benefit ($)	Benefit/ Cost Ratio
				Avg.Annual	Total Present Value					
Floodproofing/Raising of Structures	1	Steady Brook	5	9010	164,500	69,200	95,300	46,100	49,200	2.07
			10	9010	89,300	37,600	51,700	46,100	5,600	1.12
			15	9010	60,000	25,200	34,800	46,100	-11,300	0.75
	2	Russell	5	1940	35,400	18,800	16,600	21,100	-4,500	0.79
			10	1940	19,200	10,200	9,000	21,100	-12,100	0.43
			15	1940	12,900	6,800	6,100	21,100	-15,000	0.29
	3	Harrison	5	5140	93,800	24,800	69,000	20,100	48,900	3.43
			10	5140	51,000	13,500	37,500	20,100	17,400	1.87
			15	5140	34,200	9,000	25,200	20,100	5,100	1.25
	4	Governors Point	5	840	15,300	0	15,300	15,700	-400	0.97
			10	840	8,300	0	8,300	15,700	-7,400	0.53
			15	840	5,600	0	5,600	15,700	-10,100	0.36
Channel Excavation/ Dredging	1	Steady Brook	5	9010	164,500	0	164,500	169,600	-5,100	0.97
			10	9010	89,300	0	89,300	160,300	-71,000	0.56
			15	9010	60,000	0	60,000	157,000	-97,000	0.38

NOTES: (1) All damages, benefits and costs are expressed as a present value, unless otherwise noted

(2) All schemes assume a 50-yr. project life and are intended to provide protection to the 1:100 year flood event.

8.0 FINAL CONCLUSIONS AND RECOMMENDATIONS FOR PHASE II ANALYSES

Conclusions

1. The average annual flood damages in the study area floodplain have been estimated to be about $16,930. Using a discount rate of 10% and project life of 50 years, the corresponding present worth or value of flood damages is about $167,800.

2. On the basis of economics only, the most attractive structural scheme for alleviating flood damages is floodproofing and raising of structures in Steady Brook (Damage Centre No. 1) and Harrison (Damage Centre No. 3). None of the structural benefits examined had a positive economic benefit for the Russell or Governors Point reaches, Damage Centres No. 2 and 4 respectively.

3. The structural alternative of channel excavating and dredging at the mouth of Steady Brook, while not appealing from an economic viewpoint, warrants serious consideration as a potential flood mitigative measure. An exact economic evaluation could not be conducted due to the unpredictability of ice jams and associated flood damages, etc. However, the proposed scheme would reduce the potential for ice jamming at the mouth of Steady Brook with a corresponding reduction in the potential for personal injury, loss of life and flood damages.

4. The sensitivity analyses indicate that the economic evaluation of alternatives is sensitive to the chosen discount rate. Care should be taken in determining which discount rate is most appropriate before proceeding to construction.

5. The most attractive non-structural measure was the maintenance of the status quo. However, this measure does not reduce the risk to life or health hazards associated with the existing flooding on Steady Brook and the Humber River.

Recommendations

1. It is recommended that floodproofing and raising of selected structures be implemented in the floodplain areas of Steady Brook and Harrison to alleviate potential flood losses.

2. It is recommended that the maintenace of the status quo be adopted for the areas of Russell and Governors Point. Similarly, this approach warrants consideration for those areas of Steady Brook and Harrison not protected by floodproofing. This approach assumes that a form of compensation for flood damages would be provided subsequent to a flood event.

3. To resolve the problem of groundwater flooding in Steady Brook, it is recommended that detailed site dependent evaluations be conducted to examine the efficiency of existing residential tile drainage systems in the community and to make recommendations for improved sub-surface drainage where appropriate.

4. Floodplain zoning to control future development should continue to be endorsed in the study area.

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Appendices

APPENDIX A

PHYSICAL SURVEYS AND INTERVIEWS

APPENDIX A

PHYSICAL SURVEYS AND INTERVIEWS

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APPENDIX A
PHYSICAL SURVEYS AND INTERVIEWS

A.1 Physical Surveys

The physical surveys carried out as part of the field program during June 1985 involved primarily the collection of structure first floor elevations and topographic information within the flood risk area. Cross-sections were obtained where potential structural remedial works such as berms, dykes, etc., could be constructed. The location of these surveyed cross-sections are shown on Figure A.1.

Survey work within the Community of Steady Brook was carried out by a three-man crew using conventional survey equipment and techniques. Structure floor elevations, street and driveway profiles, as well as dyke and berm alignment profiles were referenced to Geodetic Datum using benchmarks established by Nolan, Davis & Associates Limited in April 1983 (8). Transfer of elevations from benchmarks used in the 1983 hydrotechnical study to the temporary benchmarks used in this study were surveyed to third order accuracy.

Floor elevations of summer cabins and a number of permanent residences located within the 1:100 year flood level along the Humber River between Steady Brook and Governor's Point were established from contours noted on existing 1:2500 scale Flood Risk Mapping. In these instances, a point was identified on the contour closest to the structure being surveyed and the floor elevation established by backsiting on the chosen point.

Additional cross-sectional data was obtained through utilization of previous surveys (8, 21, 22) on the watershed to supplement the present investigations. The inventory of cross-sections including location and extent are given on Figure A.1. The plotted cross-sections obtained through these surveys are included at the end of this Appendix.

A comparison of the field surveys to the existing 1:2500 scale Flood Risk Mapping confirmed that the mapping met the required accuracy.

A.2 Interviews and Questionnaires

As part of the field reconnaissance and physical surveys conducted on the study area, interviews were conducted with local landowners and interested parties.

The objectives of the interviews were to collect information relating to land use, property value, structural types and a description and value of contents. As a secondary objective, the interviews allowed the opportunity to discuss historical flood conditions in the area. Social implications of proposed remedial measures and factors contributing to flooding in the study reaches were also discussed during the interviews.

i) Questionnaires

All 37 residences within the floodprone areas were visited with questionnaires distributed in the field. All landowners were requested to complete a questionnaire at the time of interview or, alternatively, at their convenience. Questionnaires not completed during the interviews (i.e. where landowners were unavailable for comment) were requested to be returned by mail.

An example of the flood damage questionnaire and summary of the completed questionnaires returned are given in Tables A.1 and A.2 respectively. Additional details on the number of respondents, etc. can be found in Section 2.4.3 of this report.

As a secondary component of the interview stage, discussions were held with local landowners to identify any potential erosion problems currently being experienced along the study reach. The effects of erosion on properties in the Steady Brook area is briefly summarized as follows:

ii) Existing Erosion Problems

Erosion along the bank of the Humber River through the Community of Steady Brook is on-going at several locations. Loss of private property has been taking place at a relatively slow rate in two areas: G. Butt property downstream of Thistledown Nursery, and K. Huxter property immediately upstream of the Nursery. Further waterfront erosion along the Huxter property has been arrested through placement of rip-rap by the owner. Erosion of the riverbank along the G. Butt property is unchecked and, based on discussions with the owner, losses over the past 20 years probably amount to between 0.5 and 1 m per year.

A more significant bank erosion problem exists along a 150 m section paralleling Aspen Drive at the east end of Steady brook. Although it is felt some of the erosion problem is related to the change in direction of flow that takes place along this reach, the more significant factor, as reported by local residents, is a combination of peak flows and high winds from the northeast. Wave action associated with these winds is reported as having the most pronounced effect at eroding the toe of the 4 to 5 m high embankment. Recent efforts to control erosion along this stretch, through construction of a ballast-crib retaining wall, have proven effective. Unfortunately, the structure is near failure primarily as a result of excessive backfill loads, inadequate design, and substandard materials.

Erosion upstream of Steady Brook was not noted as a problem since land use is primarily for agriculture purposes and, while limited erosion does occur, it is of little economic concern.

TABLE A.1

Example of Flood Damage Questionnaire

STEADY BROOK

REMEDIAL MEASURES STUDY

Nolan, Davis & Associates Limited
Cumming-Cockburn & Associates Limited

Damage Analysis Questionnaire

GENERAL

1. Name of Owner: ______________________________
2. Name of Respondent: same as above ( ) or ______________________
3. Address: ______________________________

   ____

   ____

   (property located on attached photocopy)
4. Years owned: ______________
5. Number of residents: ______

LAND USE

6. What is the land-use of the property:
   - (a) residential ____
   - (b) recreational ____
   - (c) industrial ____
   - (d) commercial ____
   - (e) institutional ____
7. If answered c, d, or e, of the above, please specify:

   ____

8. Number of buildings on property __________.

9.

	Dimension	Description	Condition			Age
1)	___ x ___	____________	A	B	C	_______
2)	___ x ___	____________	A	B	C	_______
3)	___ x ___	____________	A	B	C	_______
4)	___ x ___	____________	A	B	C	_______

10. Description of external construction material:

Building No.
same as above

1) ____
2) ____
3) ____
4) ____

11. Description of interior construction:

Building No.	Floor Material	Wall Material	Condition		
1)	______________	______________	A	B	C
2)	______________	______________	A	B	C
3)	______________	______________	A	B	C
4)	______________	______________	A	B	C
			Good	Fair	Poor

12. Is there a basement in the building(s)?

Building No.	Finished	Unfinished
1)	____	____
2)	____	____
3)	____	____
4)	____	____

Is the basement damp _____

Are sump pumps used _____

Has the basement flooded _____ how many times _____

13. Type of heating for first floor:

Primary Building		Other
Forced air	____	__________
Hot water	____	__________
Electric	____	__________

14. If forced air, what is the location of forced air vents:

Floor ____

Baseboard ____

Lower wall ____ Level above floor ____

15. General inventory of first floor contents:

(a) Living room

Article	Number	Approximate Replacement Cost	Condition		
Armchair			A	B	C
Couch			A	B	C
Chairs			A	B	C
Coffee table			A	B	C
Bookcase			A	B	C
Drapes			A	B	C
Floor lamps			A	B	C
Stereo			A	B	C
Radio			A	B	C
Piano			A	B	C
Rug			A	B	C
Sidetables			A	B	C
Table lamp			A	B	C
Television			A	B	C
Other:					
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

15. (b) Kitchen

Article	Number	Approximate Replacement Cost	Condition		
Chairs			A	B	C
Table			A	B	C
Stove			A	B	C
Refrigerator			A	B	C
Dishwasher			A	B	C
Other					
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

(c) Dining Room

Article	Number	Approximate Replacement Cost	Condition		
Chairs			A	B	C
Table			A	B	C
China Cabinet			A	B	C
Drapes			A	B	C
Side tables			A	B	C
Chest			A	B	C
Other					
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

15. (d) Bedrooms

Article	Number	Approximate Replacement Cost	Condition		
Bed			A	B	C
Chest			A	B	C
Chairs			A	B	C
Crib			A	B	C
Desk			A	B	C
End tables			A	B	C
Dresser			A	B	C
Lamps			A	B	C
Rugs			A	B	C
Other					
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

16. What appliances are in the house:

Article	Number	Approximate Replacement Cost	Condition		
Washer			A	B	C
Dryer			A	B	C
Refrigerator			A	B	C
Stove			A	B	C
Dishwasher			A	B	C
Freezer			A	B	C
Stereo			A	B	C
Television			A	B	C
Other					
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

17. Garage (if present) contents:

Article	Number	Approximate Replacement Cost	Condition		
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			A	B	C
			Good	Fair	Poor

FLOODING HISTORY

18. Has property ever experienced flooding: ______ yes ______ no

19. If yes, how many times (frequency) has flooding occurred ________
____.

20. What years did flooding occur ________________________________.

21. Was there any damage due to flooding: ______ yes ______ no
(If yes, go to question 22
if no, go to question 24)

22. What was the estimated cost of damage and provide a brief description of the damage: $__________
____
____
____

23. Was a claim filed for the damages: ______ yes ______ no
If so, what was claimed: $__________
what was paid: $__________
Agency which paid: ____________________

24. Was the flood water: (a) fast flowing ______
(b) ponding ______

25. If flooding occurred, was access to the property cut off:
yes ______ no ______

26. Was work missed due to flooding (i.e. due to cut-off access routes, or time off for clean-up): yes ______ no ______

If yes, what is the estimated value of missed work $__________

How many hours were missed ______

27. Do you consider the flooding problem a threat to life:
yes ______ no ______

28. Any further comments with respect to flooding and incurred damage:

____

____

____

____

29. The following section is for agricultural areas only:

- frequency of flood damages on farm lands ______________

  ____

- approximate annual agricultural loss due to flooding:
  $______________

- any flood damages to buildings/sheds or contents yes____ no ____

- type of crop damaged by flooding ______________________

  ____

- number of acres affected ______________________________

TABLE A.2
SUMMARY OF DAMAGE QUESTIONNAIRES

Yrs. Occ.	Land Use	Age of Struc.	Value of Contents ($)	Basement/ Finishing	Garage/ Shed Contents ($)	Flood History/ Occurrence/ Type	Lost Income To Floods	Access Rest-ricted	Damages Incurred ($)	Comments/Other
13	R	15	N/A	finished basement	N/A	5 yrs, 1974-80 basement & property	N/A	No	$ 5,000	- fast flowing water - flooding due to ice jams @ swimming pool - sump pumps used
10	R	10	N/A	Unfinish. basement	N/A	10-12 times basement flooded; property twice in 1975 & 1980	$1,000 (80-100 man-hours)	Yes	$ 2,000	- floods 1-2 times annually - sumps used occasionally
7	R	19 9	$24,050	no basement	$18,000	property flooded in 1976 & 79	$2,000	Yes	N/A	- flood damages incurred but no estimates given - fast flowing water
11½	R	11½	$27,200	Finished basement	N/A	basement annually; property annually since 1975	$2,000 (3-4 days)	Yes	$ 5,000	- sump pumps used - fast flowing water - 1 ac. cash crop garden affected - boats used to get off property

SUMMARY OF DAMAGE QUESTIONNAIRES (cont'd)

Yrs. Occ.	Land Use	Age of Struc.	Value of Contents ($)	Basement/ Finishing	Garage/ Shed Contents ($)	Flood History/ Occurrence/ Type	Lost Income To Floods	Access Rest-ricted	Damages Incurred ($)	Comments/Other
4-5	R	4-5	$13,055 (26,555)	unfinished basement	N/A	N/A	$0	Yes	$ 0	- sumps are not used - property has been flooded - ponded water - flooding due to TCH
22	R	20	$90-120,000	finished basement	$18,500	basement 4 times; house flooded 4 times; property 12 times; worst in memory 1969, 1978, 1983, 1984	-	Yes	$5700 each time	- no sumps - market value estim. @ $340,000 by owner (incl. contents) - water comes from ground (rising) - signif. erosion - owner states flooding only by g/water - only occurs when Bowater spills - 1/8 ac. agr. land affected
	S	15								
	S	2								
16	R	16	$42,600	finished basement	$5,000	basement 12 times; property 10 times; (1969,73,75, 76,77.78,80 81,82,83)	$2,000 (16 hrs)	No	$15,000	- sumps are used - floods sometimes - owner suggests Kruger Power Co. start drawdown in Apr. rather than May

SUMMARY OF DAMAGE QUESTIONNAIRES (cont'd)

Yrs. Occ.	Land Use	Age of Struc.	Value of Contents ($)	Basement/ Finishing	Garage/ Shed Contents ($)	Flood History/ Occurrence/ Type	Lost Income To Floods	Access Rest-ricted	Damages Incurred ($)	Comments/Other
8	-	-	-	-	-	-	-	-	-	- refused to complete form but indicated value of home at $150,000
13	R S	24 5	(1)	finished	N/A	basement once 1979 minor in 1982	$1000	No	$10,000	- no sumps, basement flooded once - ponding water
30	R	18	$15,000	unfinished	-	basement 12 times over 30 yrs.; never on 1st floor	-	No	-	- no sumps used - council appraisal of land $40,000 house $29,500 (total = $69,500) - groundwater flooding
5	R R S	45 3 5	N/A	no finished no	-	none	none	No	0	- basement never flooded - property never flooded

SUMMARY OF DAMAGE QUESTIONNAIRES (cont'd)

Yrs. Occ.	Land Use	Age of Struc.	Value of Contents ($)	Basement/ Finishing	Garage/ Shed Contents ($)	Flood History/ Occurrence/ Type	Lost Income To Floods	Access Rest-ricted	Damages Incurred ($)	Comments/Other
30	R	30	$14,930	no basement	None	None	0	No	0	- never any flooding on property
35	R	35	$65,000	finished	N/A	None	0	No	0	- never any flooding on property
35	C									
		35	-	N/A	N/A	5 times in 25 yrs.	$10,000 (4 days)	No	$10,000	- fast flowing and ponding - 1969 worst flood year - inc. freq. lately (avg. 1:5 years)

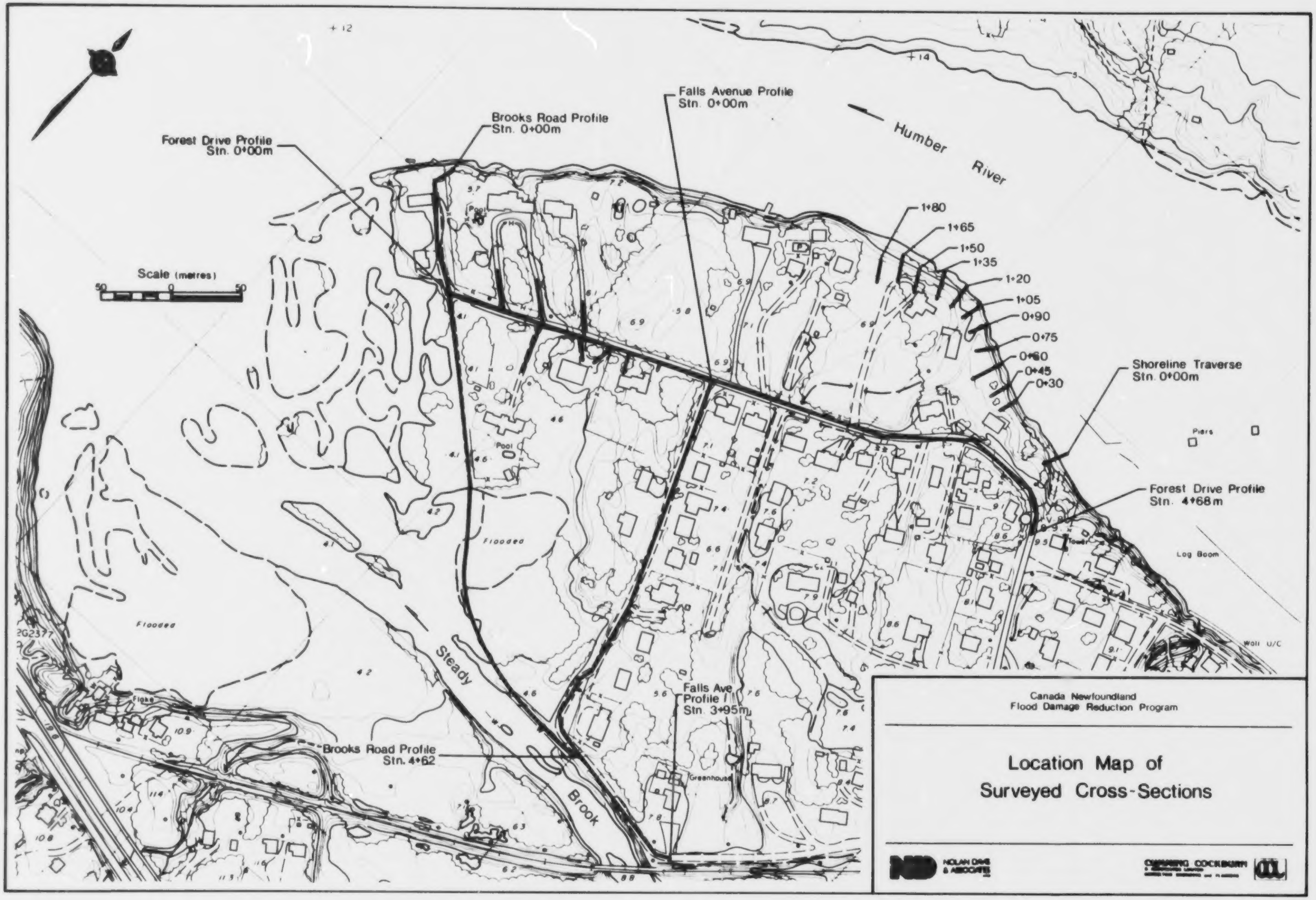
NOTES: - Average retail market housing price in Steady Brook $55,000 to $60,.000 for homes under 20 yrs. old Highly variable for older buildings. (Source: Thorne Real Estate Ltd., Corner Brook)
- Average retail market housing prices along the Humber River $35,000 to $45,000 for homes under 20 yrs. old (Source: Thorne Real Estate Ltd., Corner Brook)

TABLE A.2 (cont'd)

SUMMARY OF DAMAGE QUESTIONNAIRES

Index to Abbreviations

Yrs. Occ.	Years of Occupancy
Conc. found.	Concrete Foundation
N/A	Not Applicable
-	No Information Given
R	Residential
C	Commercial
ac.	acre
g/water	groundwater
agr.	Agricultural
t & g	tongue and groove
Struc.	structure
S	shed


+12
Scale (metres)
50
0
50
Forest Drive Profile
Stn. 0+00m
Brooks Road Profile
Stn. 0+00m
Falls Avenue Profile
Stn. 0+00m
+14
Humber River
1+80
1+65
1+50
1+35
1+20
1+05
0+90
0+75
0+60
0+45
0+30
Shoreline Traverse
Stn. 0+00m
Piers
Forest Drive Profile
Stn. 4+68m
Log Boom
Pool
Flooded
Steady Brook
Falls Ave
Profile
Stn. 3+95m
Greenhouse
Brooks Road Profile
Stn. 4+62
2G2377
Wall U/C

Canada Newfoundland
Flood Damage Reduction Program

Location Map of
Surveyed Cross-Sections

NOLAN DAVIS & ASSOCIATES

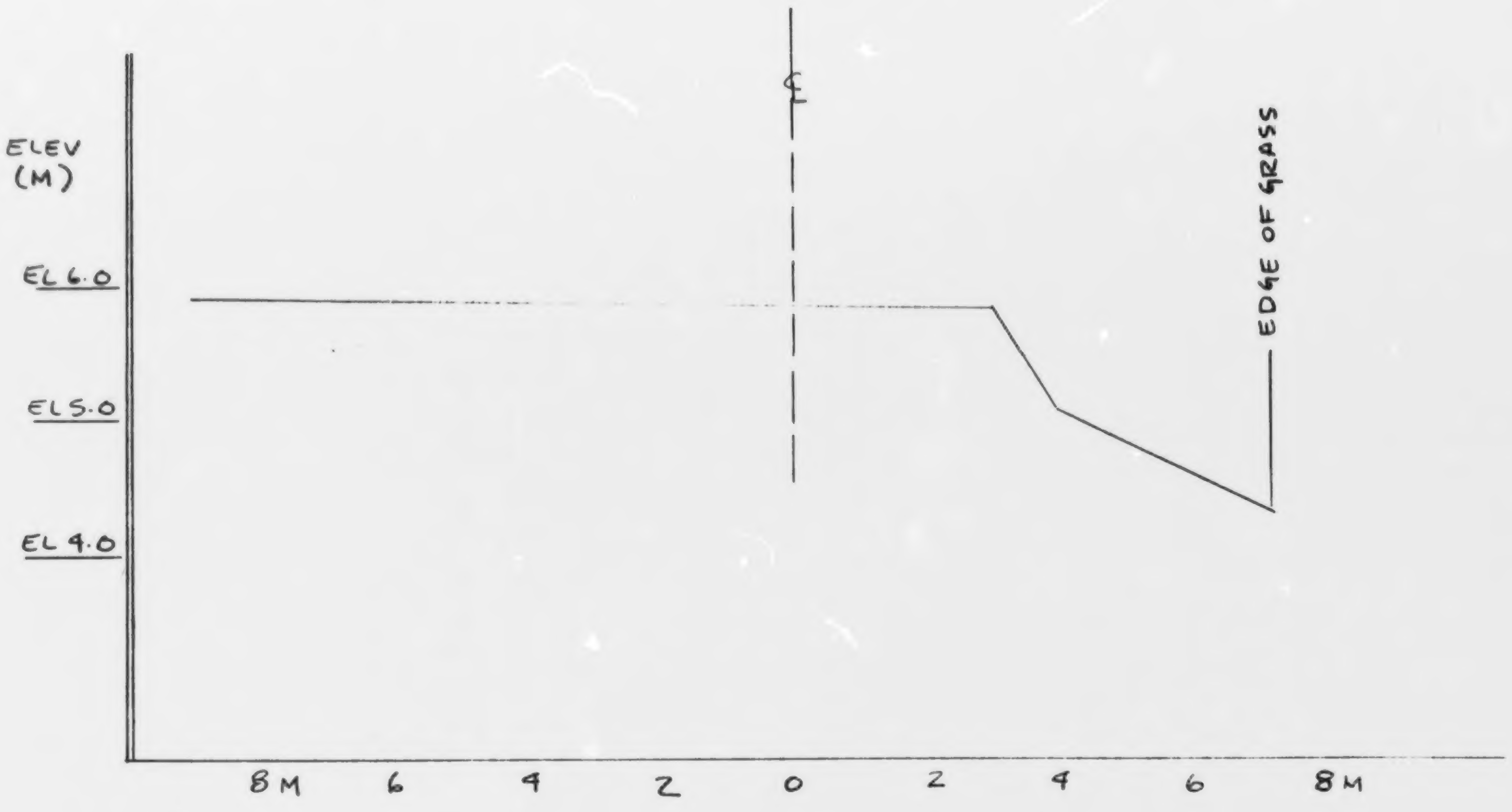
CUMMING COCKBURN

Figure A.1

SURVEYED

CROSS-SECTIONS

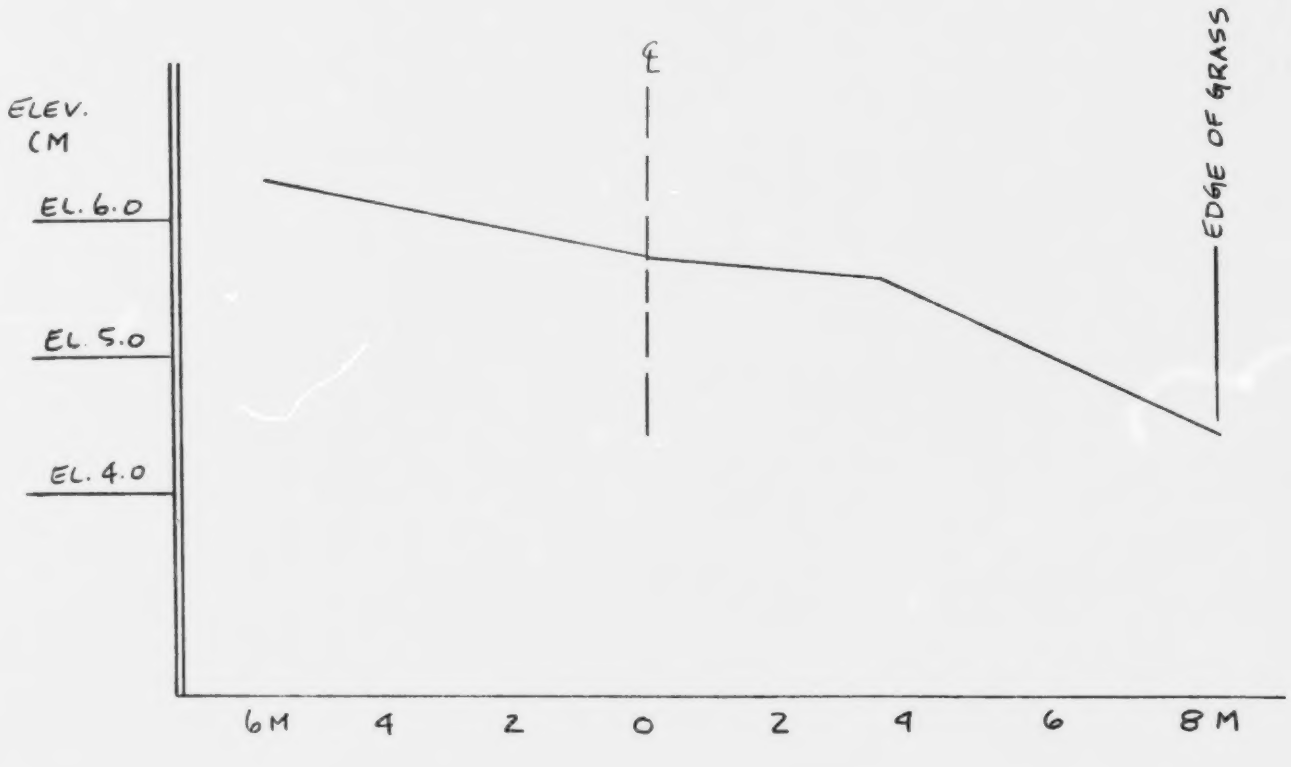
NOLAN-DAVIS & ASSOCIATES LTD.


ELEV
(M)
EL 6.0
EL 5.0
EL 4.0
℄
EDGE OF GRASS
8M
6
4
2
0
2
4
6
8M

STN 0+30.0 M

CUMMING-COCKBURN & ASSOCIATES LTD.

NOLAN-DAVIS & ASSOCIATES LTD.


ELEV.
CM
EL. 6.0
EL. 5.0
EL. 4.0
℄
EDGE OF GRASS
6M
4
2
0
2
4
6
8M

STN 0+45.0M

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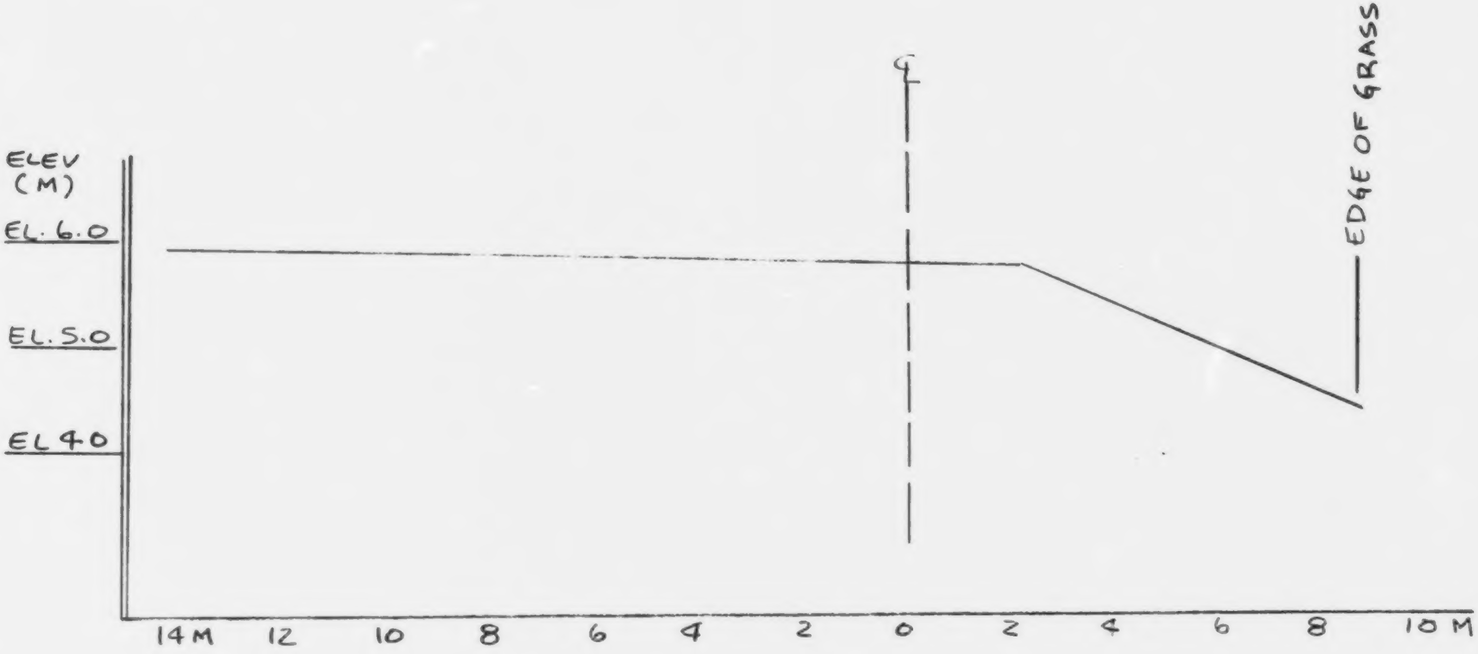
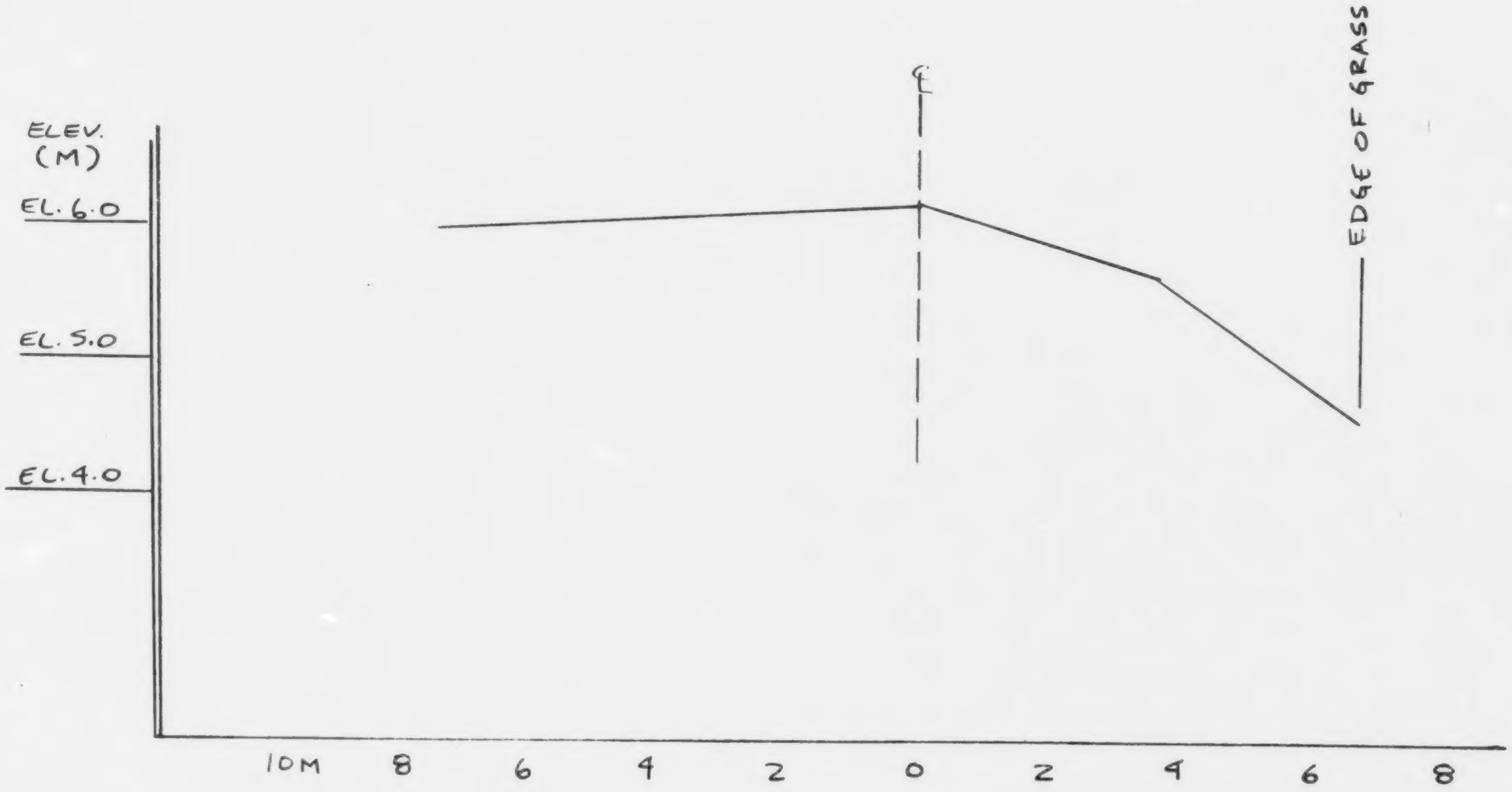

ELEV
(M)
EL. 6.0
EL. 5.0
EL 4.0
℄
EDGE OF GRASS
14M
12
10
8
6
4
2
0
2
4
6
8
10 M

STN 0+60.0 M

CUMMING-COCKBURN & ASSOCIATES LTD.

NOLAN-DAVIS & ASSOCIATES LTD.



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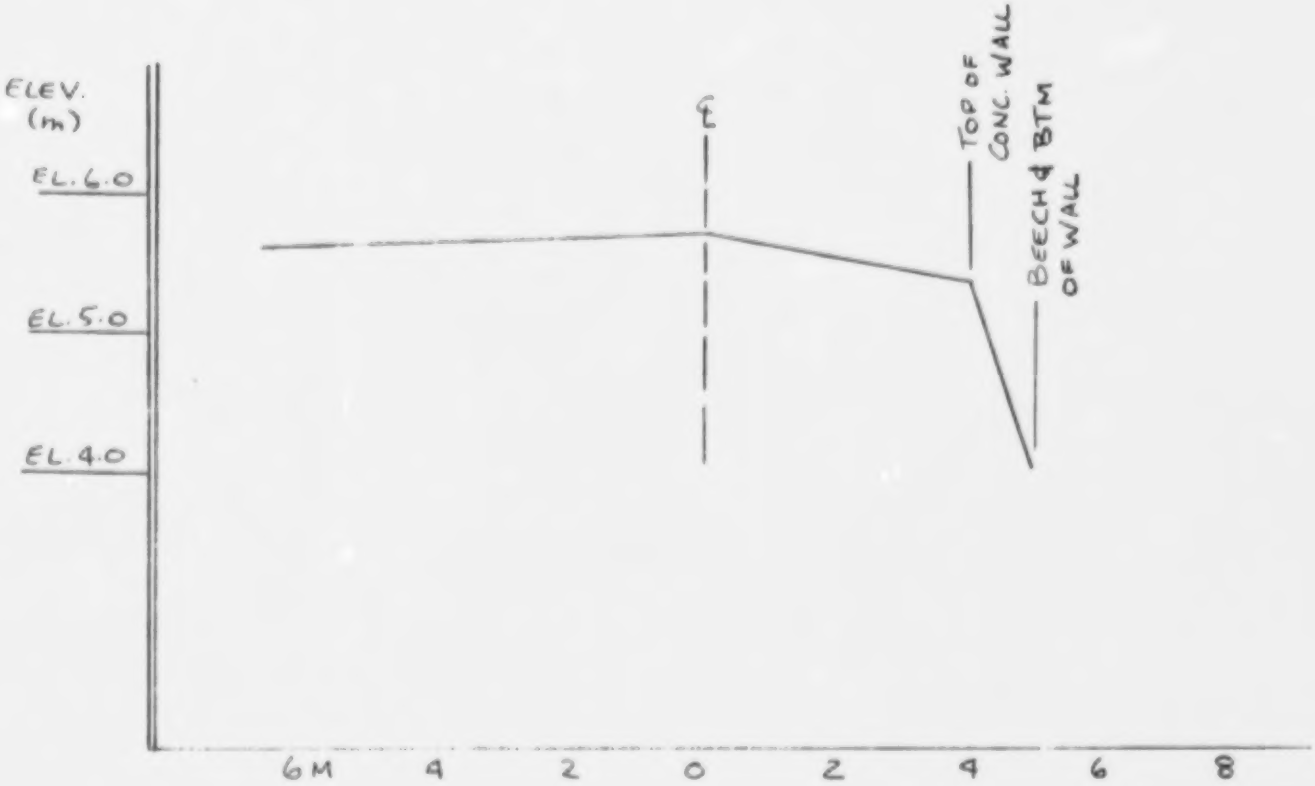
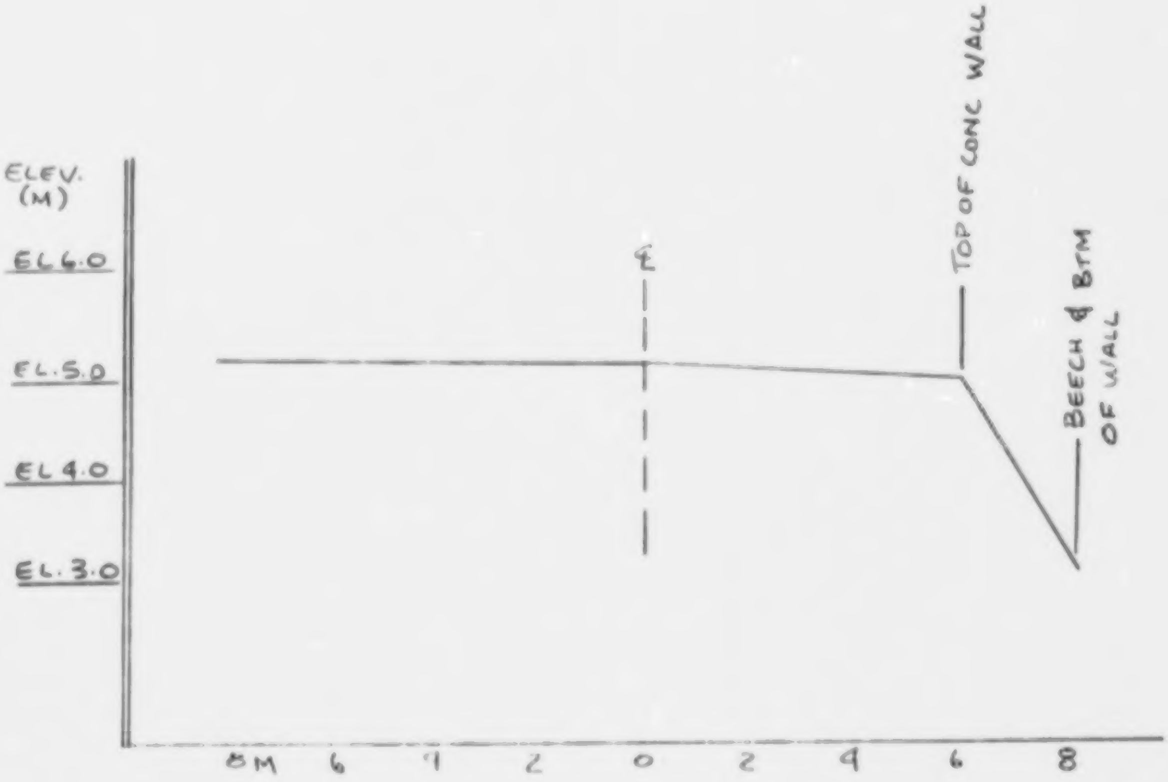
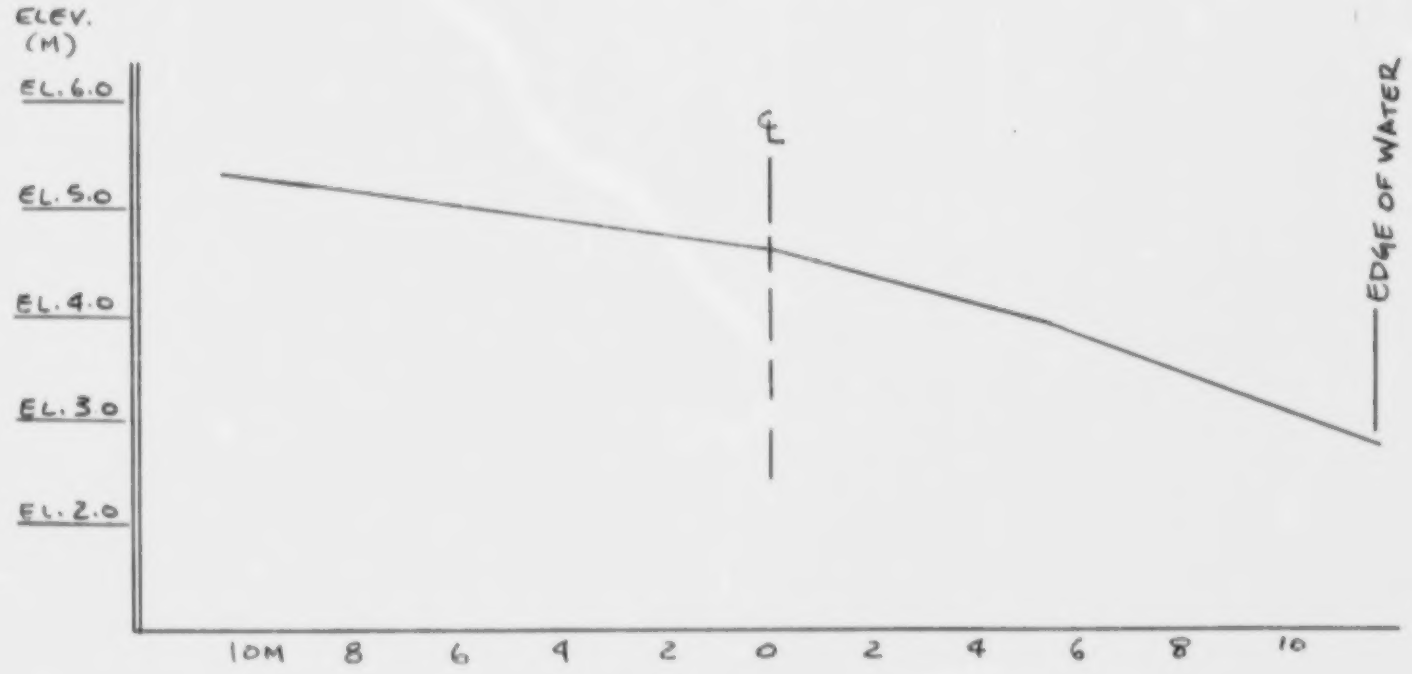

ELEV.
(m)
EL. 6.0
EL. 5.0
EL. 4.0
℄
TOP OF CONC. WALL
BEECH & BTM OF WALL
6M
4
2
0
2
4
6
8

STN 1+05


ELEV. (M)
EL 6.0
EL.5.0
EL 4.0
EL.3.0
℄
TOP OF CONC WALL
BEECH ℄ BTM OF WALL
8M
6
4
2
0
2
4
6
8

STN 1+20.0 M

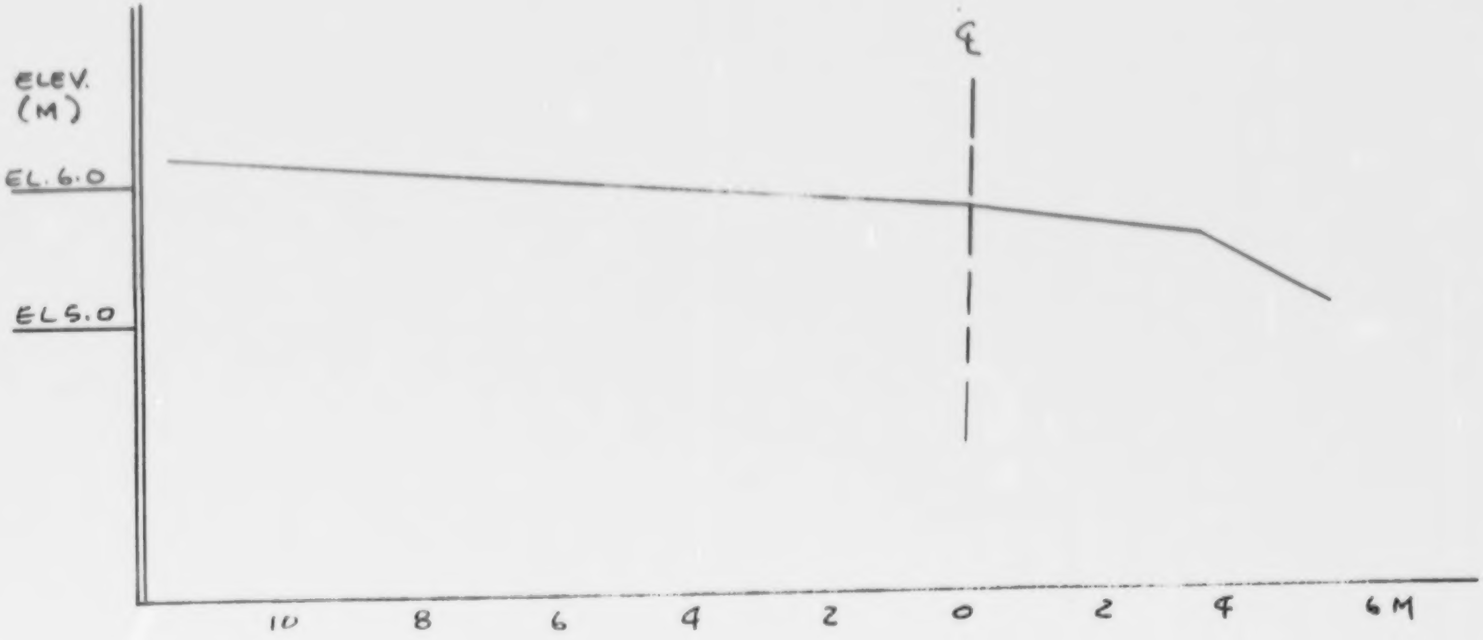
NOLAN-DAVIS & ASSOCIATES LTD.



STN 1+35.0 M

CUMMING-COCKBURN & ASSOCIATES LTD.

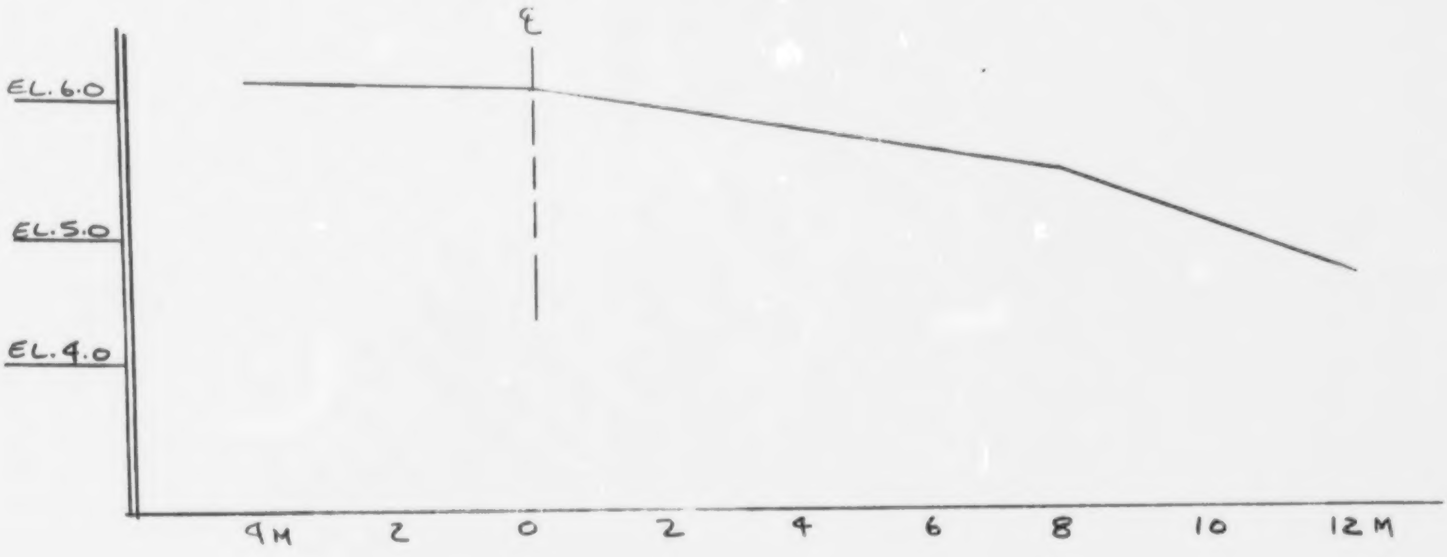
NOLAN-DAVIS & ASSOCIATES LTD.


ELEV.
(M)
EL. 6.0
EL 5.0
℄
10
8
6
4
2
0
2
4
6 M

STN 1+50.0 M

CUMMING-COCKBURN & ASSOCIATES LTD.

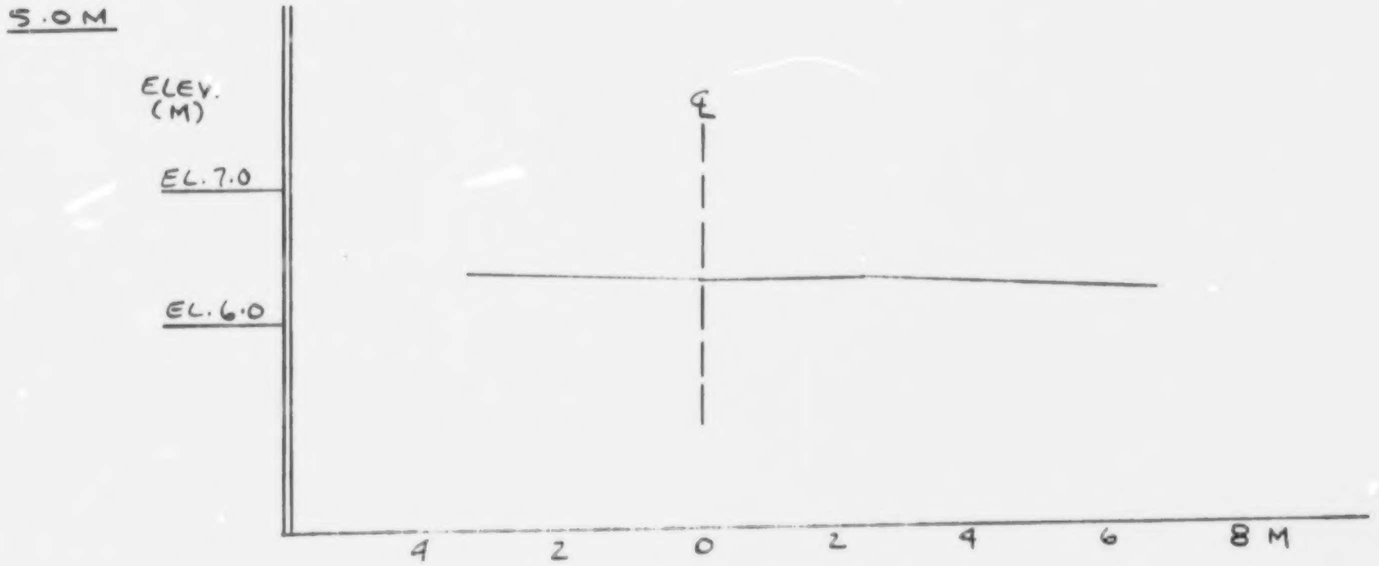
NOLAN-DAVIS & ASSOCIATES LTD.


℄
EL.6.0
EL.5.0
EL.4.0
4M
2
0
2
4
6
8
10
12M

STN 1+65.0 M

CUMMING-COCKBURN & ASSOCIATES LTD.

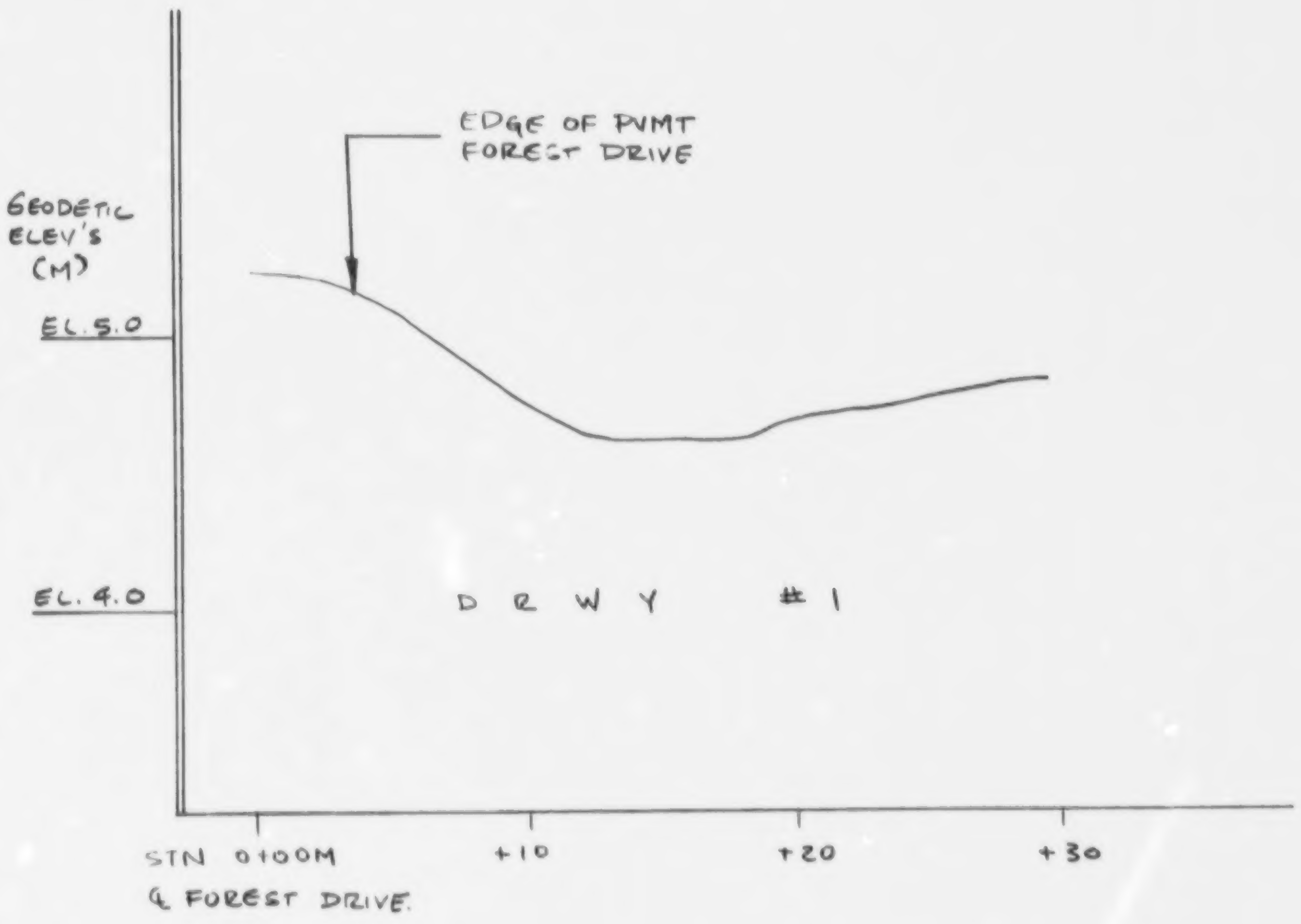
NOLAN-DAVIS & ASSOCIATES LTD.


5.0M
ELEV.
(M)
EL.7.0
EL.6.0
℄
4
2
0
2
4
6
8 M

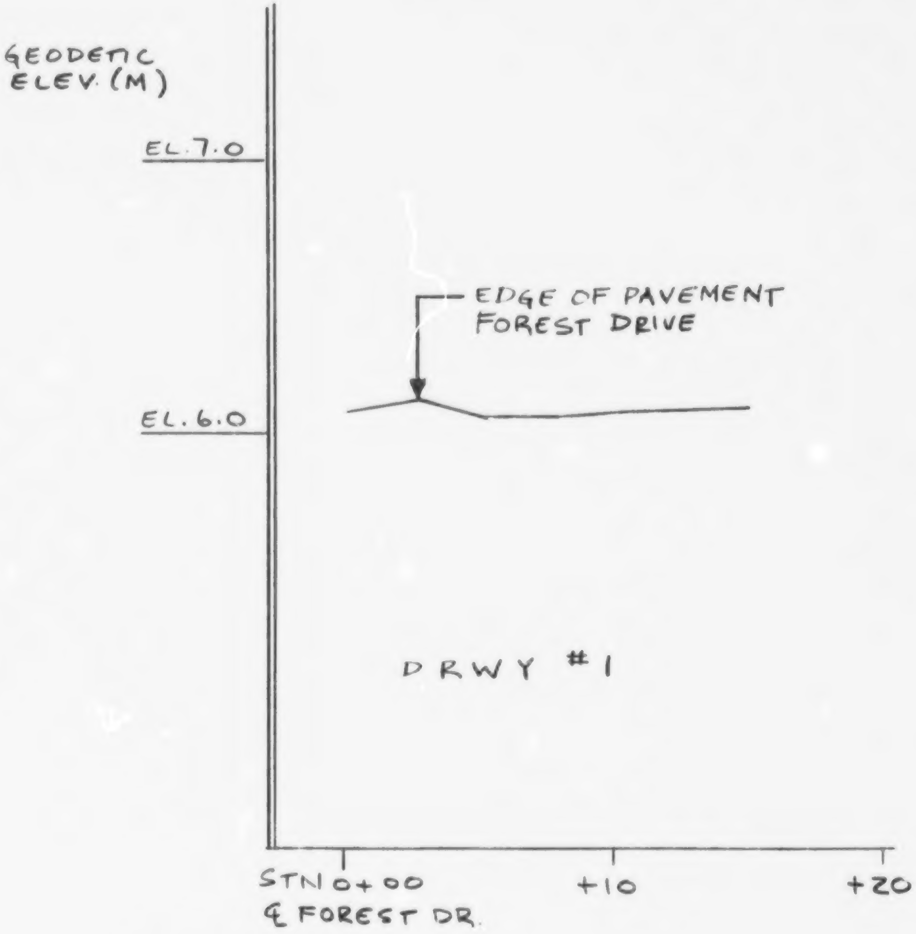
STN 1+80.0M

DYKE #1
ROWE'S

CUMMING-COCKBURN & ASSOCIATES LTD.

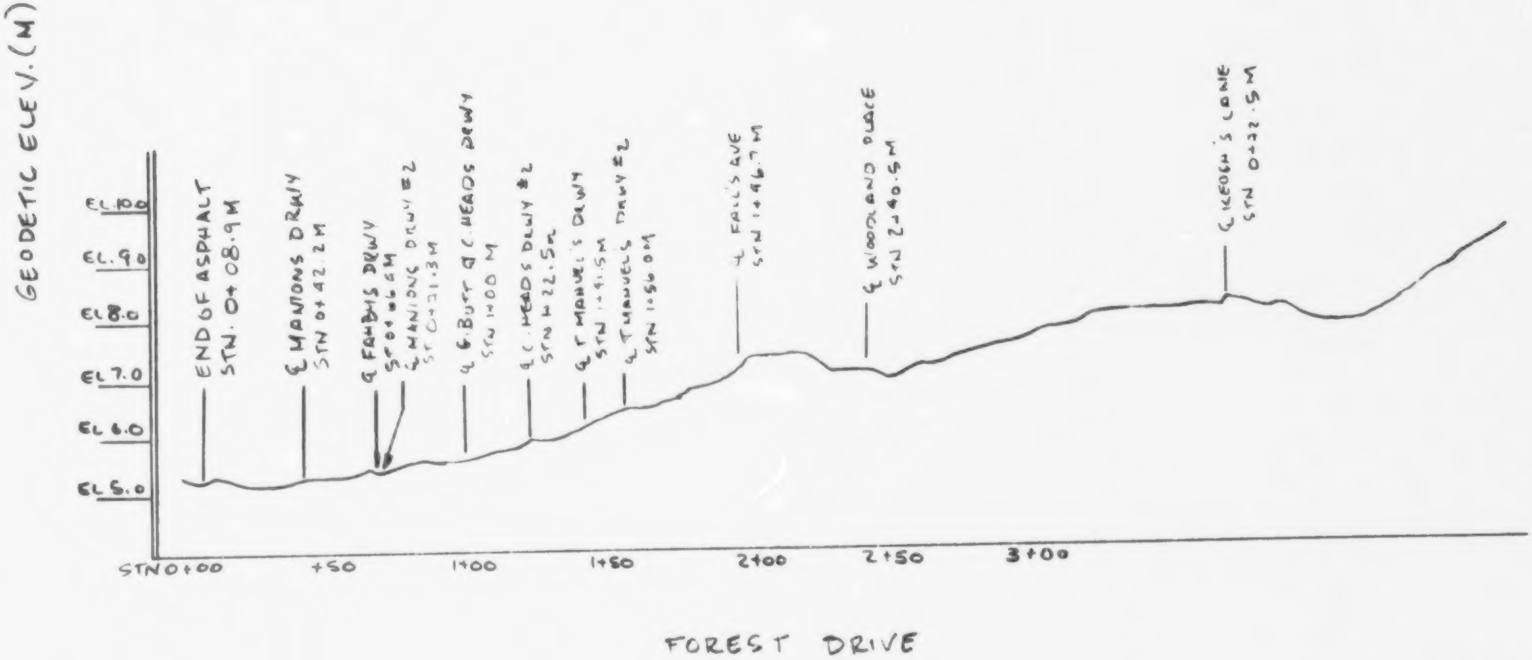

EDGE OF PVMT
FOREST DRIVE
GEODETIC
ELEV'S
(M)
EL. 5.0
EL. 4.0
D R W Y #1
STN 0+00M
℄ FOREST DRIVE.
+10
+20
+30

McLAN-DAVIS & ASSOCIATES LTD.


GEODETIC ELEV. (M)
EL. 7.0
EL. 6.0
EDGE OF PAVEMENT FOREST DRIVE
DRWY #1
STN 0+00 ℄ FOREST DR.
+10
+20

CUMMING-COCKBURN & ASSOCIATES LTD.

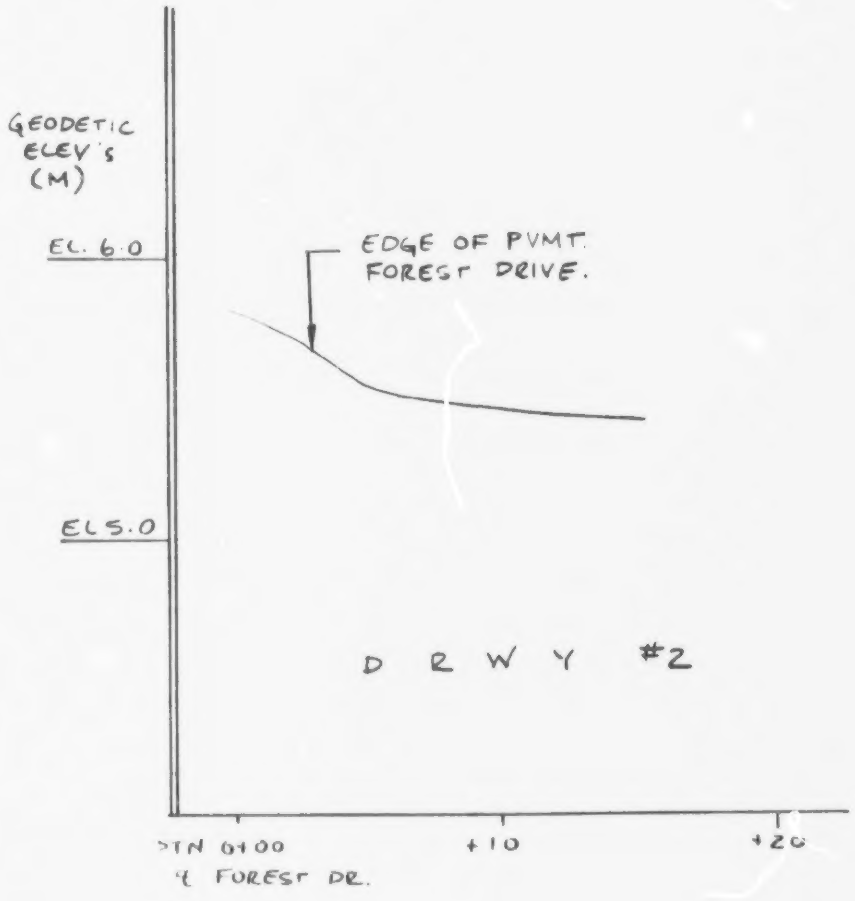
NOLAN-DAVIS & ASSOCIATES LTD.



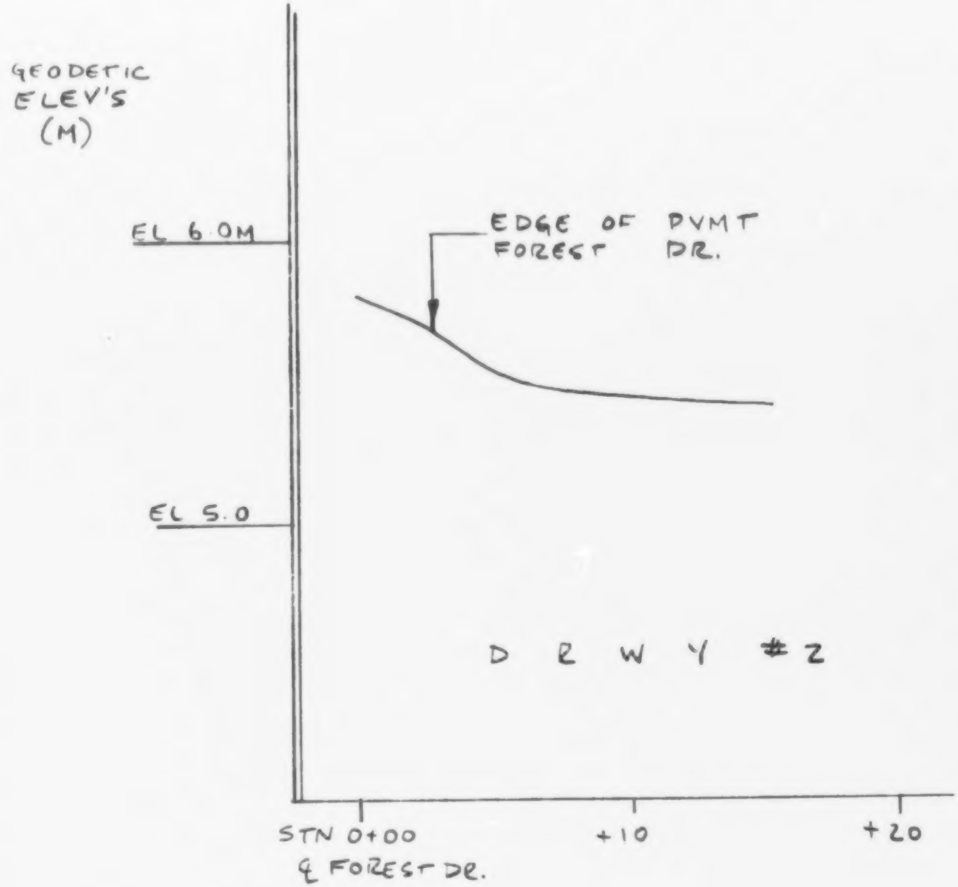
FOREST DRIVE

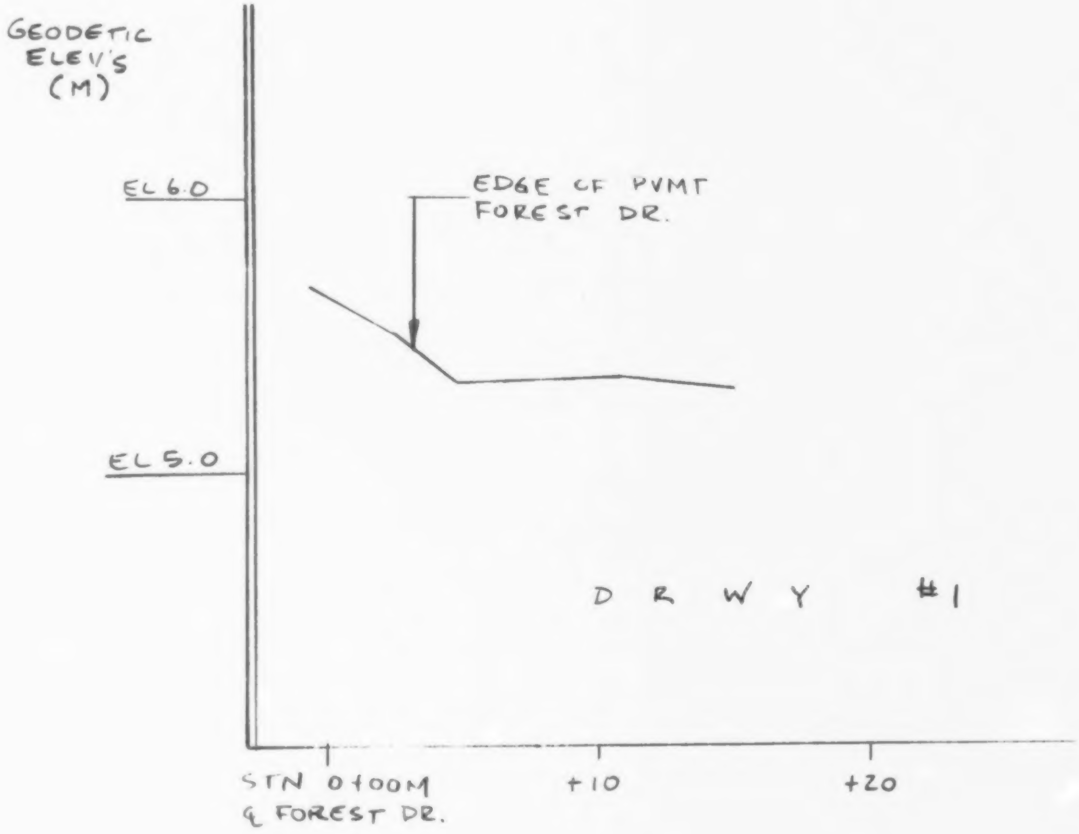
CUMMING-COCKBURN & ASSOCIATES LTD.

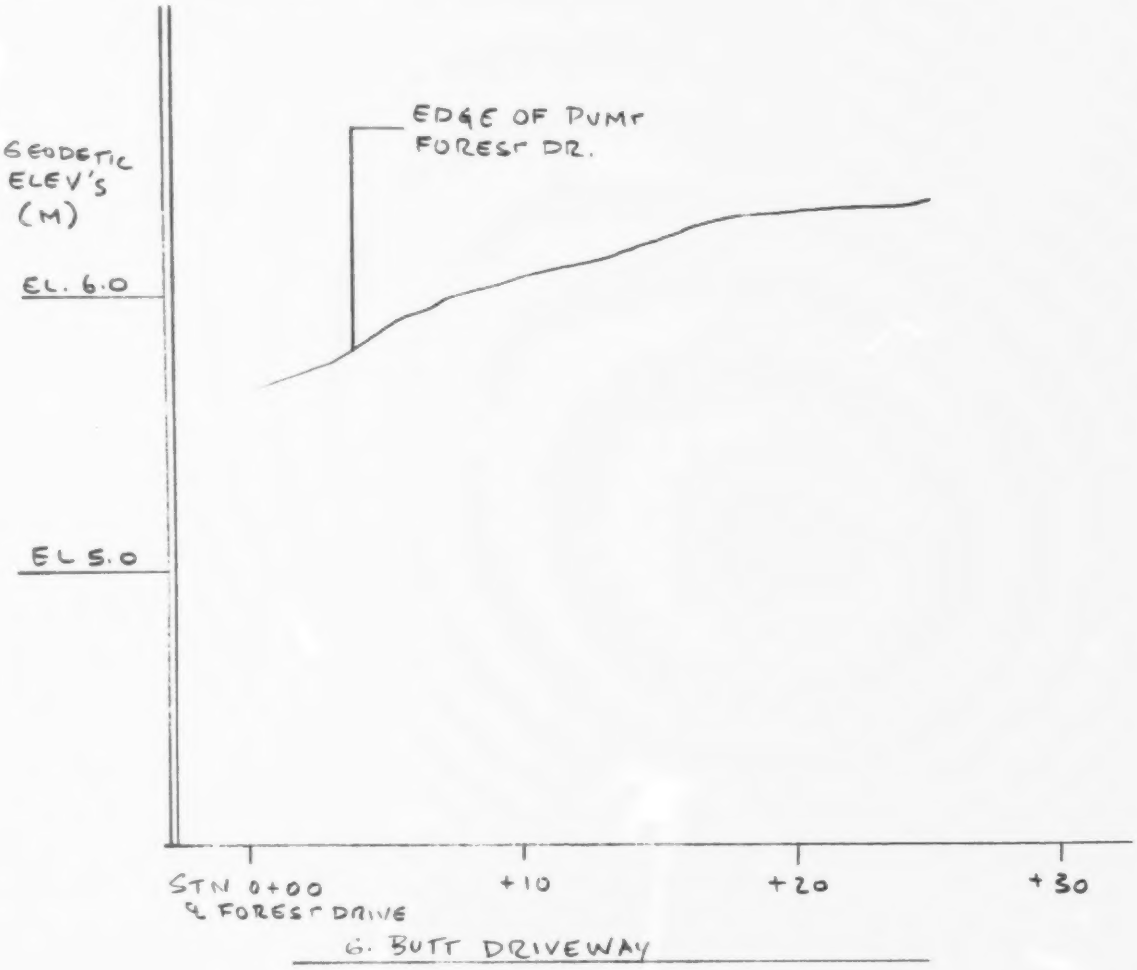
NOLAN-DAVIS & ASSOCIATES LTD.


GEODETIC
ELEV'S
(M)
EL. 6.0
EL 5.0
EDGE OF PVMT.
FOREST DRIVE.
D R W Y #2
STN 0+00
℄ FOREST DR.
+10
+20

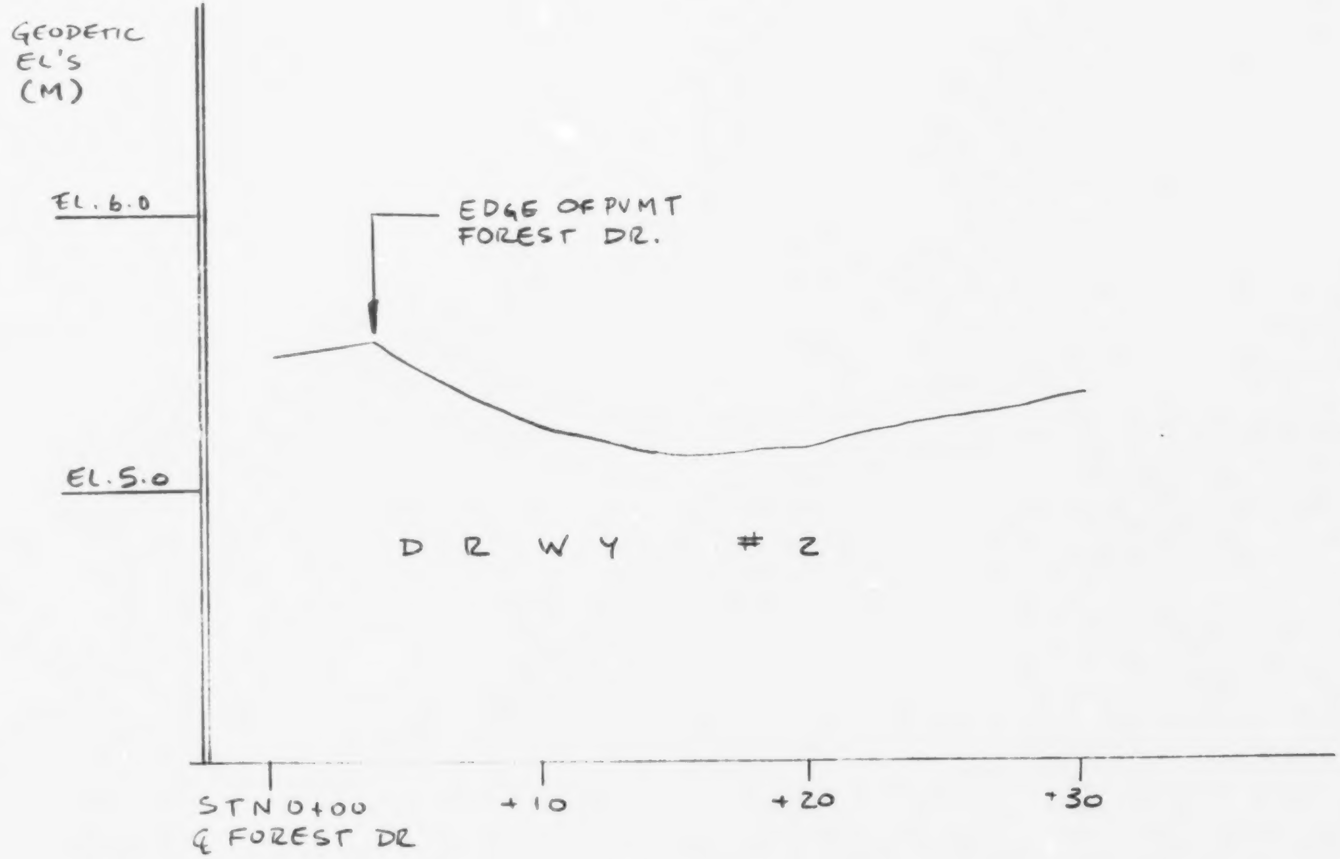
CUMMING-COCKBURN & ASSOCIATES LTD.


GEODETIC
ELEV'S
(M)
EL 6.0M
EL 5.0
EDGE OF PVMT
FOREST DR.
D R W Y #2
STN 0+00
℄ FOREST DR.
+10
+20

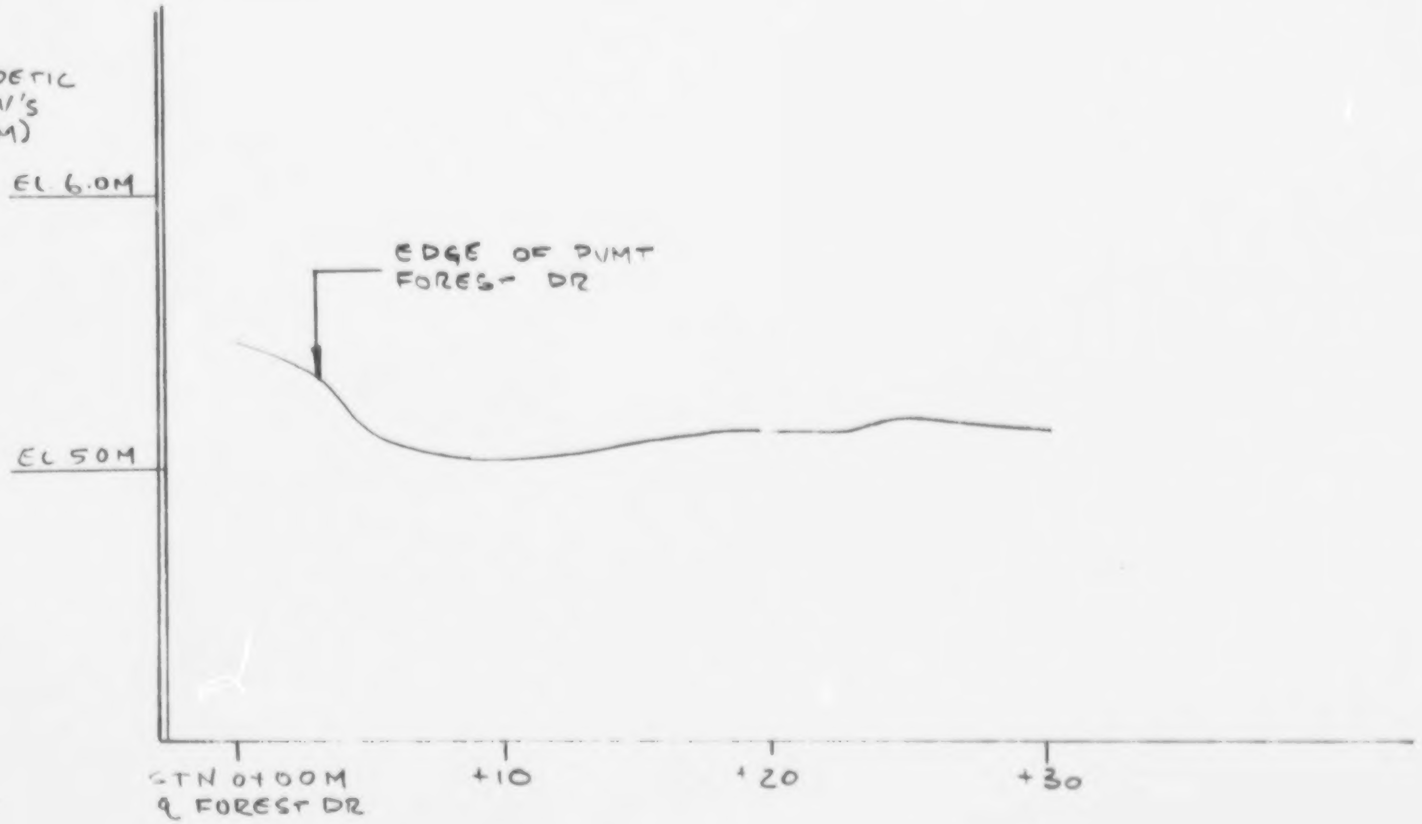

GEODETIC
ELEV'S
(M)
EL 6.0
EL 5.0
EDGE OF PVMT
FOREST DR.
D R W Y #1
STN 0+00M
℄ FOREST DR.
+10
+20


GEODETIC ELEV'S (M)
EL. 6.0
EL 5.0
EDGE OF PUMT FOREST DR.
STN 0+00
℄ FOREST DRIVE
+10
+20
+30
6. BUTT DRIVEWAY

NOLAN-DAVIS & ASSOCIATES LTD.

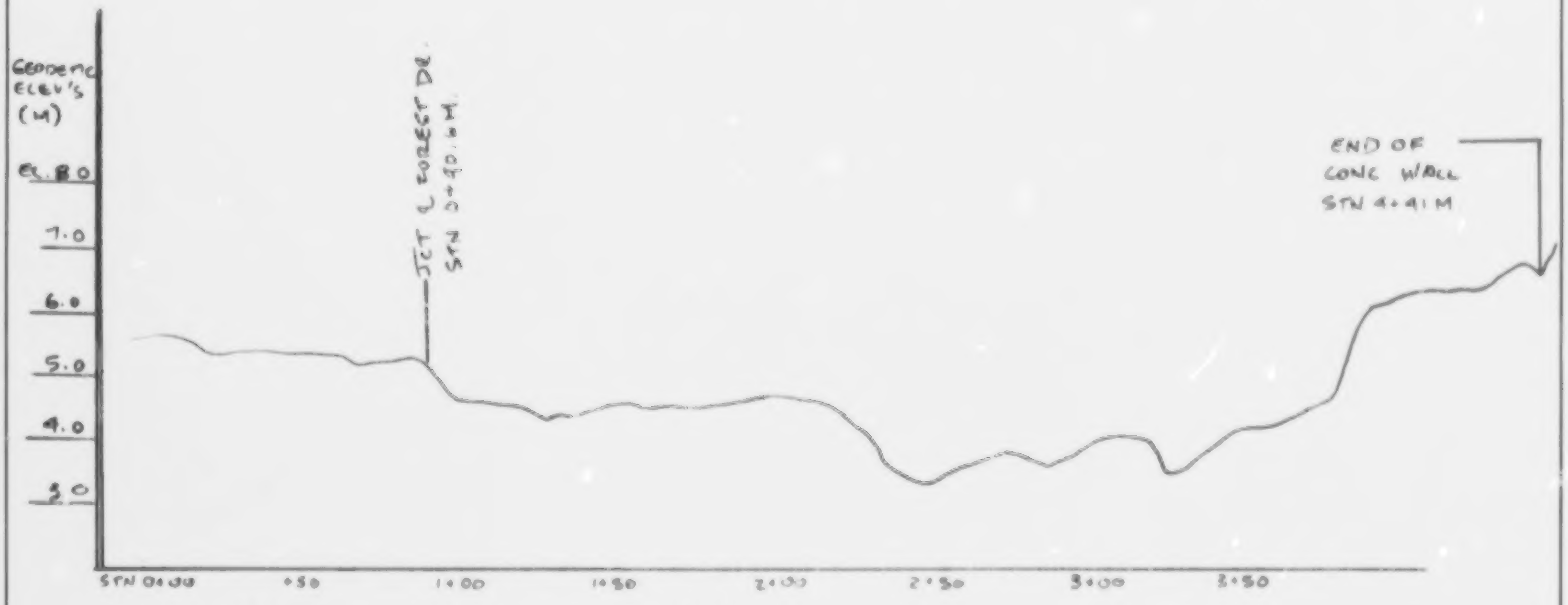

GEODETIC
EL'S
(M)
EL. 6.0
EL. 5.0
EDGE OF PVMT
FOREST DR.
D R W Y # 2
STN 0+00
℄ FOREST DR
+10
+20
+30

CUMMING-COCKBURN & ASSOCIATES LTD.



#2 B FAHEY DRIVEWAY

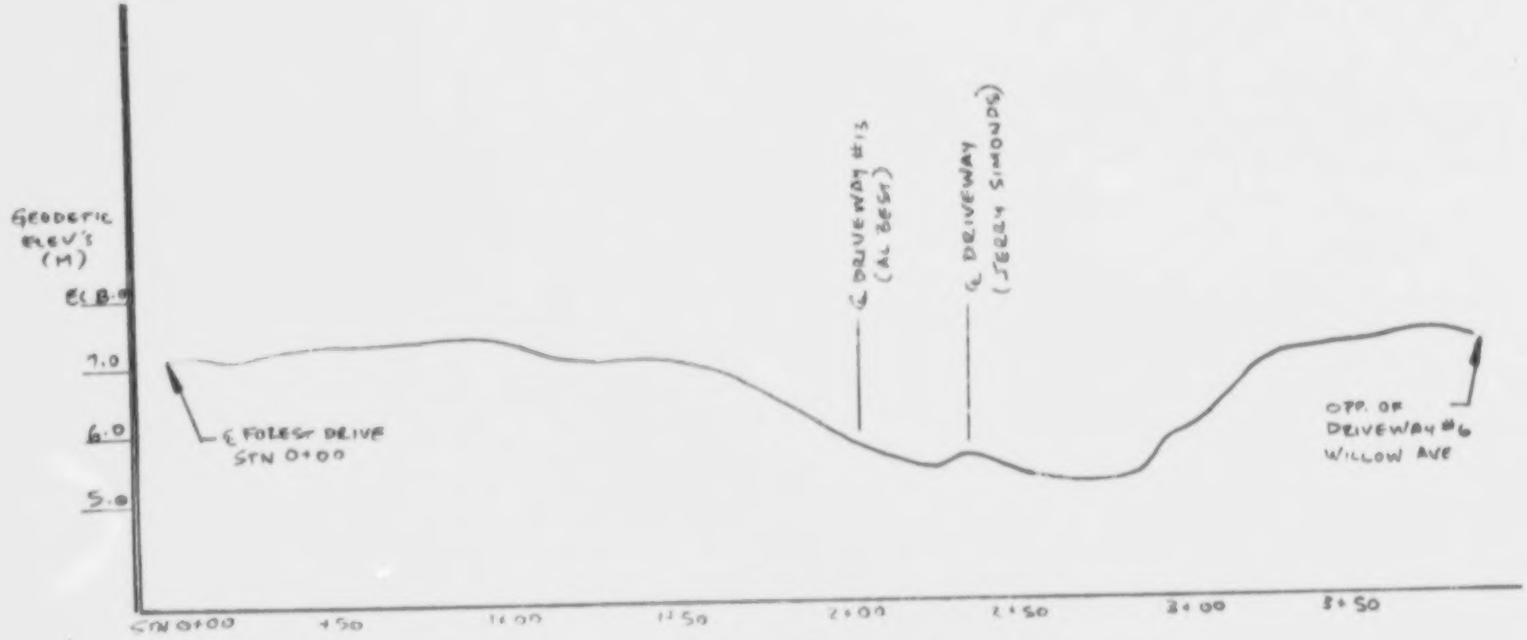
NOLAN-DAVIS & ASSOCIATES LTD.



BROOK ROAD

CUMMING-COCKBURN & ASSOCIATES LTD.

NOLAN-DAVIS & ASSOCIATES LTD.



FALL'S AVENUE

CUMMING-COCKBURN & ASSOCIATES LTD.

APPENDIX B

BACKGROUND FOR ECONOMIC ANALYSIS

APPENDIX B

BACKGROUND FOR ECONOMIC ANALYSIS

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APPENDIX B
BACKGROUND FOR ECONOMIC ANALYSES

B.1 Damage Assessment

B.1.1 General

The following tasks were undertaken in order to identify and quantify the potential for flood damages within the study area:

- Detailed field reconnaissance and topographic surveys to allow for the definition of such factors as:
  - the number and type of dwellings subject to a flood risk
  - provide housing stock information of the flood prone dwellings
  - social and environmental considerations of any potential remedial work scheme
  - provide detailed information pertaining to the location of any potential remedial work scheme
- Distribution of questionnaires to supplement the information obtained through the above, and to provide a source which would aid in the regionalization of existing generic flood damage curves
- Conduct background research of any relevant reports pertaining to historical flood losses in the area, remedial measures recommended or undertaken, and market estimates of the value of properties within the flood risk area
- Review and regionalize existing generic, synthetic damage curves to evaluate the relationship between flood level and associated flood damages. These curves were based on data and techniques discussed in a report on flooding events in Ontario by Paragon Engineering Limited (24).

The following sections provide additional information concerning the flood damages and cost-benefit calculations.

B.1.2 Determination of Structural Classifications

Houses were classified according to the following types: (Paragon (24)):

Group 1 : One storey detached home, no basement
Group 2 : One storey detached home, with basement
Group 3 : Two storey detached home, no basement
Group 4 : Two storey detached home, with basement
Group 5 : Split level
Group 6 : Townhouses
Group 7 : Mobile Homes

The results of the field reconnaissance survey were then extrapolated to incorporate all structures in the floodplain. On the basis of the inventory undertaken for the Steady Brook study area, the classification scheme was expanded to reflect the particular nuances of the study area. As a result of similar previous investigations assessing flood damages (4,5,6), garages and sheds were categorized as having the associated damage equivalent to 25% of the damage experienced by a Group 1 structure under the same depth of flooding.

It should be noted that of the seven main classification groups, and one sub-group (sheds, garages, etc.), only Groups 1, 2, 4 and the sub-group were used in this analyses. No structures classified under Groups 3, or 5 through 7 were found within the flood risk area.

Evaluation of commercial structures was also not warranted as, with the exception of one commercial greenhouse/nursery, no such structures are exposed to a flood risk within the study area. The evaluation of damages associated with the greenhouse/nursery for a specific flood event was based on the results of the damage questionnaires and discussions with owners of similar establishments in the region.

B.1.3 Composite Stage-Damage Curves

i) Assessment of Damages Based on Questionnaires

Data was gathered through background research (i.e. conversations with local residents, utility companies and community officials) and flood damage questionnaires.

The objectives of the questionnaire were primarily:

- to identify and quantify flood damages to residents from any historical flooding events experienced in the study area
- to estimate the replacement cost of any home contents exposed to a flood risk and to provide for the development of stage damage curves for the area
- to address any social or environmental concerns currently affecting the study reach
- to solicit local opinion on potential remedial work alternatives and as to the causes of the existing flooding condition.

The questionnaire was distributed during the field reconaissance surveys and was designed to cover residences subjected to a flood damage risk.

An example of the questionnaire distributed about the study area can be found in Table A.1. A summary of the completed questionnaires returned is given in Table 2.1 and expanded upon in Table A.2.

ii) Assessment of Damages Based on Generic Damage Curves

Because of the lack of confidence and limited quantitative data gathered in the questionnaires, the use of synthetic generic damage curves was adopted.

Although the estimation of flood damages is conceptually simple, substantial problems exist in specific applications. The problems in estimation that arise are generally the result of data limitations relative to damages incurred in response to varying flood levels.

In attempts to provide components of the quantification necessary for the estimation of flood damges, a number of studies have been carried out. In general terms, these studies have developed generic residential damage curves relying on either incidents of damage and/or synthetic procedures involving surveys of homes at risk. In undertaking these studies, one of two approaches have been adopted:

a) the derivation of synthetic damage estimates - this relies on field surveys of homes with the categorization of the structural and commodity damages that would arise with increasing levels of inundation.

b) surveys of damage, after specific flooding events. These incidents of damage studies are useful but have shortcomings including:

    - problems with not collecting sufficient information, and in a suitable form for detailed analyses
    - problems with not including all relevant aspects of damages
    - some studies have only tabulated damages which relate specifically to "essentials of life", such as furnaces and water heaters. This problem has arisen because of imposed restrictions on damages that are subject to compensation.
    - different methods of reporting damages have been used; for example, damage as a percentage of property value as opposed to damage as a percentage of market value of the dwelling alone, or as absolute dollar damages, have been utilized.

Other restrictions and concerns pertaining to the existing documentation assessing the determination of flood damages includes:

- many flood-related damages are related to basement flooding. The forthcoming of the "home-handyman" and changing lifestyles have resulted in a substantial increase in basement remodelling. As a result the potential exists for more valuable goods and structural damages to be incurred during basement flooding, than were identified in studies undertaken 10 to 20 years ago (23).

- there has been difficulty in categorizing homes in studies. Verbal descriptions for categories must, of necessity, be generic and yet specific residences are difficult to assign to a category. As a result of concerns in part arising from potential misclassifications, a series of adjustment factors have been developed.

Due to the concerns such as those outlined above, a study was carried out in 1985 by Paragon Engineering Ltd. (24) for the Ontario Ministry of Natural Resources. This study resulted in the development of generic stage-damage curves for different house types for use in the economic evaluation of flood mitigative schemes.

The base generic stage-damage curves, shown on Figure B.1, were subsequently adjusted to account for the regionalization differences between Ontario and Newfoundland, as discussed in the following section.

B.1.4 Regionalization of Composite Curves

i) Direct Damages

Due to inherent differences with respect to housing indices between Ontario and Newfoundland, the generic Paragon curves were adjusted to reflect local market conditions.

Based on a survey of house sale prices in the Steady Brook area (27, 30), discussions with real estate agents (30), and a comprehensive assessment of the responses received from the damage questionnaires, it was concluded that adjustments to the structure damage curves were not warranted. An upward adjustment was, however, required for the content damage to account for regional economic differences.

The questionnaires were used to determine replacement costs of home furnishings which were then compared to the associated items used by Paragon in the development of their content damages. The net differences in the total cost of each item were then derived, and averaged.

It was found that Paragon curves underestimated the content damage estimates in the Steady Brook area by about 68%. The content component of the generic curves was, therefore, adjusted upward by this percentage. The adjusted content component was then added to the structural damage component of the generic curves resulting in the definition of regionalized stage-damage curves applicable for use in this study.

A comparison of the composite generic stage-damage curves to the developed regionalized stage-damage curves for each structure group are given on Figure B.1.

ii) Indirect Damages:

In addition to direct damages to the residential sector, indirect damages were also estimated. Based on previous reports (4,5,6,23,24), these damages are generally assumed to be in the order of 10-15 percent of the residential damage for a given flood event. Due to the low flood duration time associated with events in the study reaches, a value of 10 percent of the residential damage was assumed appropriate for this project.

In order to account for direct damages to utilities, an indirect method of calculation must be applied. Therefore, for ease in the development of damage estimates and application of the resultant stage-damage curves, utility damages were assessed as being 10 percent of the direct physical damages, according to guidelines derived by Environment Canada (12). Utilities refer to such operations as municipal services, communications companies and hardware, and energy installations.

Transportation damages were assumed to be 10 percent of the direct physical damages. This factor was derived based on a review of the existing transportation network within the study area and on the duration of flooding given a specific storm event. Transportation damages include damages to roads, highways, railroads and marine services.

In summary, the direct damage estimates to the Steady Brook area as a result of flooding were increased by 30% to account for the above mentioned indirect damage potential.

Damages to agricultural and recreational sectors were addressed independently based on discussions with local agencies, landowners and real estate companies. However, no significant damages were identified and a detailed evaluation of these items was not warranted.

B.2 Methodology for Economic Analysis

B.2.1 General

The basic principle upon which the benefit-cost analyses are based is that flood damage to an individual structure, group of structures, or floodplain reach can be estimated by evaluating the dollar value of independent damage causing floods and by estimating the frequency of each flood depth. For a single known flood event, the damage caused is estimated directly from a depth (stage)-damage relationship. When it is required to compute the average damage expected in any year, then the damage corresponding to each depth of flooding is weighted by the percent chance of each depth occurring (damage caused by more infrequent events being weighted the least). The sum of the weighted damage represents the expected annual flood damage.

If the damage and frequency relationships remain unchanged each year, then the expected annual value represents the damage which can be expected to occur during any one year. However, in practice, either one or more relationships are likely to change over time; therefore, the expected annual value will also change. This results in a non-uniform annual distribution of expected values over time. To compare the magnitude of damage of alternative plans or to compare damage with costs, an equivalent annual value is computed. This equivalent value represents a uniform distribution (the same each year) of annual values and is computed by discounting and amortizing each year's expected annual damage value over the period of analysis. The discounting and amortization takes into account the time value associated with damage values.

The following briefly outlines the procedure for undertaking the economic analyses:

1. Examine the flood hazard area(s) and classify by land use (structure type)
2. Determine flood damage categories by land use (see Figure 2.6)
3. Develop appropriate depth versus damage curves using computed flood levels and damage values as interpreted directly or from previous damage analyses (see Appendix B.1)
4. Identify damage centres in the flood prone area based on the limits and/or degree of potential remedial schemes and/or on areas subject to an equivalent flood depth
5. Determine the expected total damage under existing conditions for all storm events assessed
6. Weight the total expected damage from each storm event by the percent chance of occurrence and sum the weighted values. This represents the expected annual flood damage
7. Repeat steps 4 through 6 for various potential remedial work schemes and subtract the expected average annual damages for the remedial work scheme from the do-nothing (existing condition) alternative. This gives the expected average annual benefit
8. Select the time horizon based on the life expectancy of the remedial work scheme
9. Select an appropriate discount rate
10. Using the uniform series Present Worth Factor for the interest rate and time horizon selected, bring the benefits back to the present time frame

11. Compare the benefits with the costs of the capital works. If the ratio of benefit/cost is greater than 1.0, then the scheme is feasible from an economic viewpoint.

B.2.2 Determination of Average Annual Damages and Benefits

For each storm event and flood mitigative scheme evaluated, the regionalized generic stage-damage curves as given on Figure B.1 were applied. The associated flood depth for the event and scheme at each structure was entered on the curve and the total expected flood damage to the structure was determined. This was repeated for each structure within a predefined damage centre, with the sum total of the expected direct damage to the reach by event and scheme determined. These totals were then increased by 30% to account for indirect damages and plotted as shown on Figure B.2.

The U.S. Army Corps of Engineers Expected Annual Flood Damage Model, or EAD, was then applied to determine the average annual flood damage of each mitigative scheme (33).

In utilizing the EAD model, there are several different combinations in which the stage, flow, damage and frequency data can be processed to develop the damage-frequency relationship. The simplest way is to relate stage or flow to damage and stage or flow to frequency. If the damage and frequency data are not directly related to a common parameter then another relationship must be used. This is commonly a stage-flow relationship. Thus, if damage is expressed as a function of stage and frequency as a function of flow, or vice versa, damage can be related to frequency with the stage-flow function.

Because these stage, flow, frequency and damage relationships vary along a river, it is common practice to divide a river into reaches and let a set of these relationships represent the stage, flow, frequency and damage data for a reach. An index location is selected within the reach and a single stage or flow-frequency relationship and stage-flow relationship are applied at that location and considered representative of these variables for the entire reach. In the case of damage, several relationships are usually used, each representative of a particular damage category.

Expected annual damage is the damage which can be expected to occur in any one year assuming conditions remain unchanged. It is computed by weighting each damage value according to its probability of occurrence. Graphically this amounts to finding the area beneath the damage-frequency curve (integrating) over the entire range of damaging events. It needs to be emphasized that the correct computation of expected damage includes the full range of probabilities from initial threshold to zero. Any truncation, that is, not going to 0 or to the threshold will result in an error which can be significant depending upon the shape of the function.

An example integration or weighting of the damage values for the Steady Brook area illustrating the basic method used in the EAD modelling is given in Table B.1 and shown graphically on Figure B.2.

For a more detailed description of the EAD model, and methodology employed in determining the average annual damage values for the study reaches, reference is given to the EAD Users Manual (33) and Guidelines for Benefit-Cost Analyses by Environment Canada (12).

Once the expected average annual flood damages for each potential remedial scheme (including the do-nothing or existing condition) have been computed, the expected average annual benefit can be calculated. This is achieved by subtracting the average annual damage for a given remedial scheme from the existing condition, status quo alternative.

B.2.3 Present Value of Flood Mitigative Schemes

The methodology applied in the amortization of average annual benefits over the project life was based on guidelines prepared by Environment Canada for the Benefit-Cost Analysis of Flood Damage Reduction Projects (12).

Average annual benefits were compared to associated project costs of the remedial work schemes by amortizing the average annual benefit over the project life, and relating it to an equivalent Present Worth or Value (PV) through the use of a Capital Recovery Factor or CRF (19, 33).

The ultimate value of the project benefit can be derived by dividing the annual benefit of the prospective capital works scheme by the CRF. The Capital Recovery Factor provides for a means of comparing the present day cost of a capital works scheme to the ultimate benefit of the scheme, accounting for the cost to finance the scheme, versus the rate of inflation, projected over the project life. The general form of the equation for deriving the Capital Recovery Factor can be given as:

$$\mathrm{CRF} = \frac{i\,(1+i)^n}{(1+i)^n - 1} \qquad \text{(B.1)}$$

where CRF = Capital Recovery Factor
i = "real" discount rate (net of inflation)
n = index year or project life of the capital works scheme

When any present sum of money (for example, the project cost) is multiplied by the CRF for "n" year and interest rate "i", the product is an annual figure sufficient to repay exactly the present sum in "n" years with interest rate "i". Conversely, when the annual figure (or annual benefit) is divided by the CRF, the result is an equivalent present sum of money which is directly comparable to the project cost. A standard project life of 50 years was assumed for all alternatives considered.

It should be emphasized that economic calculations of the type presented here are valid regardless of the scheme of financing to be employed. Even though it is convenient to explain the CRF in terms of a loan transaction, the computed totals are the equivalent costs whether the entire first cost of the proposed assets is to be borrowed, whether it is to be solely equity capital, or whether a combination of borrowed monies and equity capital is warranted.

The net present value (NPV) can then be found for each capital works scheme by subtracting the present value of the project costs from the present value of project benefits. The benefit-cost ratio is calculated by dividing the present value project benefit by its associated present value of costs. The following equations can be used to represent the method of calculation of the above factors:

i) Ultimate worth, related to present value, of the project benefits:

$$PV = \text{Avg. Annual Benefit}/CRF \qquad (B.2)$$

ii) Net Present Value of the Capital Works Scheme:

$$NPV = PV - \text{Capital Works Cost} \qquad (B.3)$$

iii) Benefit-Cost Ratio:

$$B/C = PV/\text{Capital Works Cost} \qquad (B.4)$$

Benefits derived from each alternative flood control measure were defined as the dollar value of all tangible flood damages which would be reduced as a result of the scheme to flood events with a magnitude equal to, or less than, a 1:100 year storm event. The benefits were then discounted at an effective (real) interest rate of 10% over the life of the flood control scheme (12). This yielded the total equivalent present value of the benefits.

It should be noted that while intangible benefits were examined as part of each analyses of potential flood mitigative schemes, associated dollar values could not be derived due to the non-predictability of such benefits. Intangible benefits which may have some bearing on the worth of a flood mitigative scheme may include:

i) Improved safety to local residences
ii) Reduced health risks associated with surcharging of sewer systems, septic beds, etc.
iii) Reduced inconvenience and worry associated with flood events

iv) Improved quality of living standards within the flood risk area

v) Encouragement of additional development within the area as a result of the increased developable land.

A summary of the results of the economic evaluation of potential remedial work schemes can be found in the main report.

B.3 Sensitivity Analyses to Applied Discount Rate

In order to assess the economics of any remedial work scheme, discount rates must be used to convert benefits into present values. These values may then be compared to the present costs of the flood damage reduction alternatives.

The effective interest rate, or "real" social discount rate, recommended for benefit-cost analyses in evaluation of public projects is 10% (12). However, the sensitivity of benefits and costs using discount rates of 5% and 15% is also recommended to provide a relative degree of confidence in a mitigative scheme, given any changes in economic climate.

Sensitivity analyses were thus conducted by amortizing the expected average annual damages over the project life (50 years) utilizing effective interest rates of 5%, 10% and 15%, and comparisons made.

Using the average annual damage of $16,930 (see Table 2.2), a present worth of benefits of $167,800 is obtained assuming complete flood protection and a discount rate of 10%. In amortizing the average annual damages by 5% and 15%, the resultant present worth in benefits is $309,000 and $112,700 respectively. These figures represent a net difference in capital available for expenditure on a flood control scheme of $196,300. This net difference may be significant in the evaluation of costs on economical acceptability of a flood damage reduction scheme.

The sensitivity analyses to applied discount rate was carried out for all structural flood damage reduction schemes evaluated. The resultant present value benefits of each scheme using varying discount rates were compared to the associated cost and the sensitivity of the scheme to the discount rate applied determined. Table B.2 summarizes the sensitivity testing carried out for the various Phase I structural alternatives.

The sensitivity of measures selected for further evaluation during the Phase II investigations were addressed independently, as discussed in Section 7.0 of this report. It should be noted that the same methodology was employed in the Phase II sensitivity analyses as is presented here.

With reference to Table B.2, it is evident that the economic viability of several of the evaluated schemes were found marginally sensitive to the discount rate applied. However, only those schemes carried over to the Phase II investigations were found to be sensitive to discount rate. This substantiates their selection for further evaluation. As one would intuitively expect, the lower discount rate of 5% resulted in higher benefit-cost ratios associated with each of the alternatives.

TABLE B.1

Example Computation of Expected Annual Damage

Damage Centre 1 : Steady Brook

Existing Conditions (2)

Frequency (1) (Events per 100 Years)	Frequency Interval (Events per Year)	Event (2) Damage ($)	Avg. Damage for Frequency Interval ($)	Weighted Annual Damage ($)
1.		165,500		
	0.01		137,200	1,370
2.		109,000		
	0.03		82,300	2,470
5.		55,700		
	0.05		39,400	1,970
10.		23,100		
	0.10		14,200	1,420
20.		5,400		
	0.66		2,700	1,780
86.		0		
		TOTAL		$ 9,010

(1) Exceedance frequency in events per 100 years, represented by the equation:

$$\text{FREQ.} = \left(\frac{1}{T}\right) 100$$

where T = return period of event

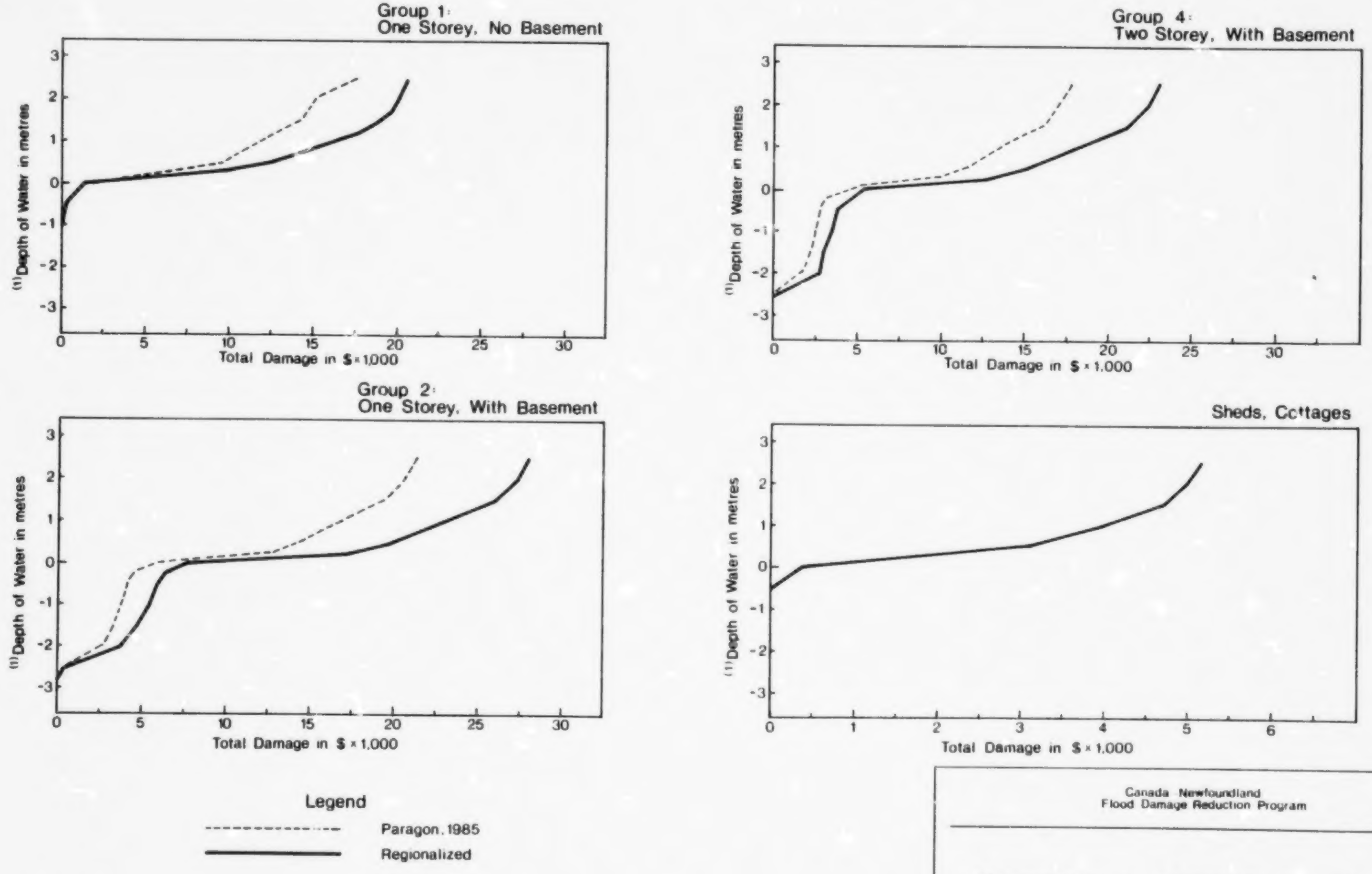
(2) Refer to Figure B.1 for graphic representation

TABLE B.2

Summary of Sensitivity Testing to Applied Discount Rates for Phase I Alternatives

Damage Centre No.	Location	Flood Mitigative Scheme	Interest Rate (%)	Mean Annual Benefit ($)	Present Value Benefit ($)	Construction Cost ($)	Benefit Cost Ratio ($)	Degree of Sensitivity
1	Steady Brook	Berms/Roadway Raising - A	5	9010	164,500	380,000	0.43	Not sensitive
			10	9010	89,300	380,000	0.24	
			15	9010	60,000	380,000	0.16	
		- B	5	6660	121,600	242,000	0.50	Not sensitive
			10	6660	66,000	242,000	0.27	
			15	6660	44,400	242,000	0.18	
		- C	5	6740	123,000	335,300	0.37	Not sensitive
			10	6740	66,800	335,300	0.20	
			15	6740	44,900	335,300	0.13	
		- D & E	5	N/A	N/A	N/A	N/A	N/A
			10					
			15					
		Raising of Structures	5	3790	69,200	27,000	2.56	Sensitive
			10	3790	37,600	27,000	1.39	
			15	3790	25,200	27,000	0.93	
		Channel Improvements/ Dredging	5	7270	132,700	103,000	1.29	Sensitive
			10	7270	72,100	103,000	0.70	
			15	7270	48,400	103,000	0.47	
2	Russell	Berms	5	N/A	N/A	N/A	N/A	N/A
			10					
			15					
		Raising of Structures	5	1360	24,830	17,900	1.39	Sensitive
			10	1360	13,500	17,900	0.75	
			15	1360	9,060	17,900	0.51	
3	Harrison	Berms	5	1280	23,400	86,300	0.27	Not sensitive
			10	1280	12,700	86,300	0.15	
			15	1280	8,520	96.300	0.10	
		Raising of Structures	5	3290	60,000	18,500	3.24	Not sensitive
			10	3290	32,600	18,500	1.76	
			15	3290	21,900	18,500	1.18	
4	Governors Point	Berms	5	N/A	N/A	N/A	N/A	N/A
			10					
			15					
		Raising of Structures	5	840	15,300	9,000	1.7	Sensitive
			10	840	8,300	9,000	0.92	
			15	840	5,600	9,000	0.62	
All		Flood Forecasting	5	6350	115,900	1,231,000	0.09	Not sensitive
			10	6350	63,000	825,700	0.08	
			15	6350	42,300	640,000	0.07	
All		Modifications to Upstream Reservoir Operation	5	16320	297,900	1,281,000	0.23	Not sensitive
			10	16320	161,800	905,700	0.18	
			15	16320	108,700	690,000	0.16	

NOTE: Only those schemes which are intended to provide protection to the mean 1:100 year flood are presented



Notes:
1 Depth of water is expressed relative to first floor elevation.
2 Damages based on June, 1985 dollar value.
3 Only those curves which are pertinent to the study area are presented.

Canada Newfoundland
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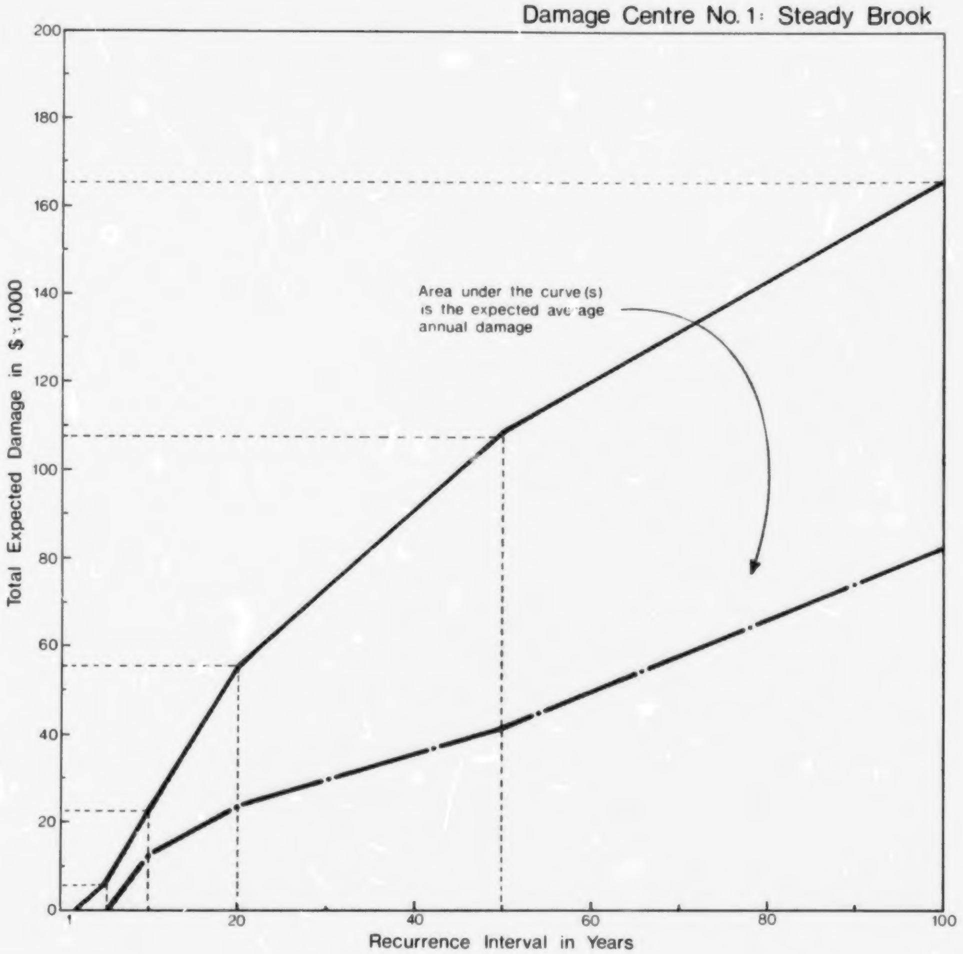
Comparison of Composite Generic to Regionalized Stage-Damage Curves

Figure B.1



Expected Annual Benefit = Existing Ave. Annual Damage – Ave. Annual Damage under Proposed Scheme

Present Value Benefit = Expected Annual Benefit ÷ CRF

CRF = Capitol Recovery Factor

Legend

——— Existing Condition Damages

—·— Damages after Floodproofing/ Raising of Structures

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Example Computation of Expected Average Annual Damage Through Frequency Integration: Steady Brook

NOLAN DAVIS & ASSOCIATES

CUMMING COCKBURN

Figure B.2

APPENDIX C
PHASE I :
CONSTRUCTION COST ESTIMATES

TABLE C.1
Construction Cost Summary

Location: Damage Centre No. 1 : Steady Brook
Scheme: A
Protection: 1:100 Year

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	3,000
2	Construction of Earth Berm			
	i) Earth Fill	12,000 m^3	7.00	84,000
	ii) Topsoil or seed	13,000 m^2	3.00	39,000
3	Supply & Placement of Rip Rap Protection	1,400 m^3	50.00	70,000
4	Supply & Place Filter Cloth	2,100 m^2	3.00	63,000
5	Installation of Drainage Culverts	11	1,000	11,000
6	Modifications to Private Entrances	-	-	
7	Raising of Roadways	-	-	
	i) Fill			
	ii) Resurfacing			
8	Land Acquisition	12,000m^2	4.00	48,000
	Sub-total			$318,000
	Contingency			32,000
	Engineering Design & Supervision			30,000
	TOTAL			$380,000

TABLE C.2

Construction Cost Summary

Location: Damage Centre No. 1 : Steady Brook
Scheme: B
Protection: 1:100 Year Mean

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	4,000
2	Construction of Earth Berm			
	i) Earth Fill	6,400 m^3	7.00	44,800
	ii) Topsoil or seed	6,500 m^2	3.00	19,500
3	Supply & Placement of Rip Rap Protection	300 m^3	50.00	15,000
4	Supply & Place Filter Cloth	600 m^2	3.00	1,800
5	Installation of Drainage Culverts	8	1,000	8,000
6	Modifications to Private Entrances	11	1,000	11,000
7	Raising of Roadways			
	i) Fill	1,600 m^3	18.50	29,600
	ii) Resurfacing	1,800 m^2	16.00	28,800
	iii) Topsoil and seed	1,300 m^2	3.00	3,900
8	Land Acquisition	6,450 m^2	4.00	25,800
	Sub-total			$192,200
	Contingency			19,800
	Engineering Design & Supervision			30,000
	TOTAL			$242,000

TABLE C.3

Construction Cost Summary

Location: Damage Centre No. 1 : Steady Brook
Scheme: C
Protection: 1:100 Year

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	3,000
2	Construction of Earth Berm			
	i) Earth Fill	11,000 m^3	7.00	77,000
	ii) Topsoil or seed	11,500 m^2	3.00	34,500
3	Supply & Placement of Rip Rap Protection	1,000 m^3	50.00	50,000
4	Supply & Place Filter Cloth	1,600 m^2	3.00	4,800
5	Installation of Drainage Culverts	11	1,000	11,000
6	Modifications to Private Entrances	5	1,000	5,000
7	Raising of Roadways			
	i) Fill	1,600 m^3	18.50	29,600
	ii) Resurfacing	700 m^2	16.00	14,400
8	Land Acquisition	12,000 m^2	4.00	48,000
	Sub-total			$277,300
	Contingency			28,000
	Engineering Design & Supervision			30,000
	TOTAL			$335,300

TABLE C.4

Construction Cost Summary

Location: Damage Centre No. 1 : Steady Brook
Scheme: D
Protection: 1:100 Year Upper 95%

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	5,000
2	Construction of Earth Berm	-	-	
	i) Earth Fill			
	ii) Topsoil or seed			
3	Supply & Placement of Rip Rap Protection	-	-	
4	Supply & Place Filter Cloth	-	-	
5	Installation of Drainage Culverts	3	1,000	3,000
6	Modifications to Private Entrances	17	1,000	17,000
7	Raising of Roadways			
	i) Fill	7,200 m^3	18.50	133,200
	ii) Resurfacing	2,500 m^2	16.00	40,000
	iii) Topsoil & Seed	4,000 m^2	4.00	12,000
8	Land Acquisition	-	-	
	Sub-total			$210,200
	10% Contingency			21,800
	Engineering Design & Supervision			25,000
	TOTAL			$257,000

TABLE C.5

Construction Cost Summary

Location: Damage Centre No. 1 : Steady Brook
Scheme: E
Protection: 1:100 Upper 95% Confidence

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	5,000
2	Construction of Earth Berm			
	i) Earth Fill	4,650 m^3	7.00	32,550
	ii) Topsoil or seed	3,800 m^2	3.00	11,400
3	Supply & Placement of Rip Rap Protection	-	-	
4	Supply & Place Filter Cloth	-	-	
5	Installation of Drainage Culverts	5	1,000	5,000
6	Modifications to Private Entrances	17	1,000	17,000
7	Raising of Roadways			
	i) Fill	7,200 m^3	18.50	133,200
	ii) Resurfacing	2,500 m^2	16.00	40,000
	iii) Topsoil and seed	4,000 m^2	3.00	12,000
8	Land Acquisition	2,400 m^2	4.00	9,600
	Sub-total			$265,750
	10% Contingency			26,250
	Engineering Design & Supervision			30,000
	TOTAL			$322,000

TABLE C.6

Construction Cost Summary

Location: Damage Centre No. 2 : Russell

Protection: 1:100 Year Mean

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization			-
2	Construction of Earth Berm			-
	i) Earth Fill			
	ii) Topsoil or seed			
3	Supply & Placement of Rip Rap Protection			-
4	Supply & Place Filter Cloth			-
5	Installation of Drainage Culverts			-
6	Modifications to Private Entrances			-
7	Raising of Roadways			-
	i) Fill			-
	ii) Resurfacing			
	iii) Topsoil and seed			
8	Land Acquisition			-
				Nil

TABLE C.7

Construction Cost Summary

Location: Damage Centre No. 2 : Russell
Protection: 1:100 Year Upper 95% Confidence

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	3,000
2	Construction of Earth Berm			
	i) Earth Fill	2,000 m^3	7.00	14,000
	ii) Topsoil or seed	3,900 m^2	3.00	11,700
3	Supply & Placement of Rip Rap Protection	400 m^3	50.00	20,000
4	Supply & Place Filter Cloth	700 m^2	3.00	2,100
5	Installation of Drainage Culverts	3	1,000	3,000
6	Modifications to Private Entrances	-	-	
7	Raising of Roadways	-	-	
	i) Fill			
	ii) Resurfacing			
	iii) Topsoil and seed			
8	Land Acquisition			
	Sub-total			$ 64,600
	Contingency			6,400
	Engineering Design & Supervision			10,000
	TOTAL			$ 81,000

TABLE C.8

Construction Cost Summary

Location: Damage Centre No. 3 : Harrison
Protection: 1:100 Year

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	1,000
2	Construction of Earth Berm			
	i) Earth Fill	1,300 m^3	7.00	9,100
	ii) Topsoil or seed	2,200 m^2	3.00	6,600
3	Supply & Placement of Rip Rap Protection	180 m^3	50.00	9,000
4	Supply & Place Filter Cloth	360 m^2	3.00	1,080
5	Installation of Drainage Culverts	2	1,000	2,000
6	Modifications to Private Entrances	2	1,000	2,000
7	Raising of Roadways			
	i) Fill	860 m^3	18.50	17,760
	ii) Resurfacing	400 m^2	16.00	6,400
	iii) Topsoil and seed	480 m^2	3.00	1,440
8	Land Acquisition	2,100 m^2	4.00	8,400
	Sub-total			$ 64,780
	Contingency			6,500
	Engineering Design & Supervision			15,000
	TOTAL			$ 86,300

TABLE C.9

Construction Cost Summary

Location: Damage Centre No. 3 : Harrison
Protection: 1:100 Year Upper 95% Confidence

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	3,000
2	Construction of Earth Berm			
	i) Earth Fill	7,200 m^3	7.00	50,400
	ii) Topsoil or seed	7,700 m^2	3.00	23,100
3	Supply & Placement of Rip Rap Protection	400 m^3	50.00	20,000
4	Supply & Place Filter Cloth	700 m^2	3.00	2,100
5	Installation of Drainage Culverts	5	1,000	5,000
6	Modifications to Private Entrances	2	1,000	2,000
7	Raising of Roadways			
	i) Fill	1400 m^3	18.50	25,900
	ii) Resurfacing	480 m^2	16.00	7,680
	iii) Topsoil and seed	800 m^2	3.00	2,400
8	Land Acquisition	6,500 m^2	4.00	26,000
	Sub-total			$167,580
	Contingency			16,320
	Engineering Design & Supervision			25,000
	TOTAL			$203,700

TABLE C.10

Construction Cost Summary*

Location: Damage Centre No. 4 : Governors Point
Protection: 1:100 Year Mean

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization			-
2	Construction of Earth Berm			-
	i) Earth Fill			
	ii) Topsoil or seed			
3	Supply & Placement of Rip Rap Protection			-
4	Supply & Place Filter Cloth			-
5	Installation of Drainage Culverts			-
6	Modifications to Private Entrances			-
7	Raising of Roadways			-
	i) Fill			-
	ii) Resurfacing			
	iii) Topsoil and seed			
8	Land Acquisition			-
				Nil

* No action necessary

TABLE C.11

Construction Cost Summary

Location: Damage Centre No. 4 : Governors Point

Protection: 1:100 Year Upper 95% Confidence

Item	Description	Unit	Unit Cost	Total
1	Site Preparation and Mobilization		L.S.	3,000
2	Construction of Earth Berm			
	i) Earth Fill	1,700 m^3	7.00	11,900
	ii) Topsoil or seed	3,800 m^2	3.00	11,400
3	Supply & Placement of Rip Rap Protection	200 m^3	50.00	10,000
4	Supply & Place Filter Cloth	500 m^2	3.00	1,500
5	Installation of Drainage Culverts	4	1,000	4,000
6	Modifications to Private Entrances	-	-	
7	Raising of Roadways	-	-	
	i) Fill			
	ii) Resurfacing			
	iii) Topsoil and seed			
8	Land Acquisition	3,700 m^2	4.00	14,800
	Sub-total			$ 56,600
	Contingency			5,000
	Engineering Design & Supervision			12,000
	TOTAL			$ 73,600

TABLE C.12

Construction Cost Summary

Raising of Residential Dwellings

Location	Scheme	Item	Description	Unit	Unit Cost	Total
Steady Brook	1:100 Year Mean Level	1	Mobilization	3	1000	$ 3,000
		2	Increase height of existing foundation wall	120 m^2	40	4,800
		3	Install basement subfloor	3	2000	6,000
		4	Raising of dwelling	3	3000	9,000
		5	Landscaping	3	500	1,500
				Sub-total		$ 24,300
				Contingency		2,700
				TOTAL		$ 27,000
Steady Brook	1:100 Year 95% Confidence	1	Mobilization	12	500	$ 6,000
		2	Increase height of existing foundation wall	530 m^2	40	21,200
		3	Install basement subfloor	12	2000	24,000
		4	Raising of dwelling	12	2500	30,000
		5	Landscaping	12	500	6,000
				Sub-total		$ 87,200
				Contingency		8,300
				TOTAL		$ 95,500

TABLE C.12 (cont'd)

Location	Scheme	Item	Description	Unit	Unit Cost	Total
Governors Point	1:100 Year Mean Level	1	Mobilization	2	500	$ 1,000
		2	Increase height of existing foundation wall	2	500	1,000
		3	Raising of dwelling	2	2500	5,000
		4	Landscaping	2	500	1,000
				Sub-total		$ 8,000
				Contingency		1,000
				TOTAL		$ 9,000
Governors Point	1:100 Year 95% Confidence Level	1	Mobilization	4	500	$ 2,000
		2	Increase height of existing foundation wall	160 m^2	40	6,400
		3	Install basement subfloor	4	2000	8,000
		4	Raising of dwelling	4	2500	10,000
		5	Landscaping	4	500	2,000
				Sub-total		$ 28,400
				Contingency		4,000
				TOTAL		$ 32,400

TABLE C.12 (cont'd)

Location	Scheme	Item	Description	Unit	Unit Cost	Total
Russell	1:100 Year Mean Level	1	Mobilization	3	1000	$ 3,000
		2	Increase foundation wall height	60 m^2	40	2,400
		3	Install basement subfloor	3	2500	7,500
		4	Landscaping	3	1000	3,000
				Sub-total		$ 15,900
				Contingency		2,000
				TOTAL		$ 17,900
Russell	1:100 Year 95% Confidence Level	1	Mobilization	5	500	$ 2,500
		2	Increase foundation wall height	100 m^2	40	4,000
		3	Raising of dwelling	5	2500	12,500
		4	Landscaping	5	500	2,500
				Sub-total		$ 21,500
				Contingency		3,500
				TOTAL		$ 25,000

TABLE C.12 (cont'd)

Location	Scheme	Item	Description	Unit	Unit Cost	Total
Harrison	1:100 Year Mean Level	1	Mobilization	2	500	$ 1,000
		2	Increase height of existing foundation wall	80 m^2	40	3,200
		3	Install basement subfloor	2	2000	4,000
		4	Raising of dwelling	2	2500	5,000
		5	Landscaping	2	500	3,000
				Sub-total		$ 16,200
				Contingency		2,300
				TOTAL		$ 18,500
Harrison	1:100 Year 95% Confidence Level	1	Mobilization	5	500	$ 2,500
		2	Increase height of existing foundation wall	324 m^2	40	13,000
		3	Install basement subfloor	5	2000	10,000
		4	Raising of dwelling	5	2500	12,500
		5	Landscaping	5	500	2,500
				Sub-total		$ 40,500
				Contingency		4,500
				TOTAL		$ 45,000

TABLE C.13

Construction Cost Summary

Dredging/Excavation

Steady Brook

Item No.	Description	Quantity	Unit Price	Total
1	Mobilization		L.S.	8,000
2	Removal of constriction within channel	9000 m^3	\$8 m^3	72,000
	Sub-total			80,000
	Contingency			8,000
	Engineering & Site Supervision			15,000
	TOTAL			\$103,000